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AERO/SPACE ENGINEERING

REVIEW OF CURRENT AND FUTURE TRENDS IN AIRCRAFT • MISSILES • ROCKETS • SATELLITES • SPACECRAFT

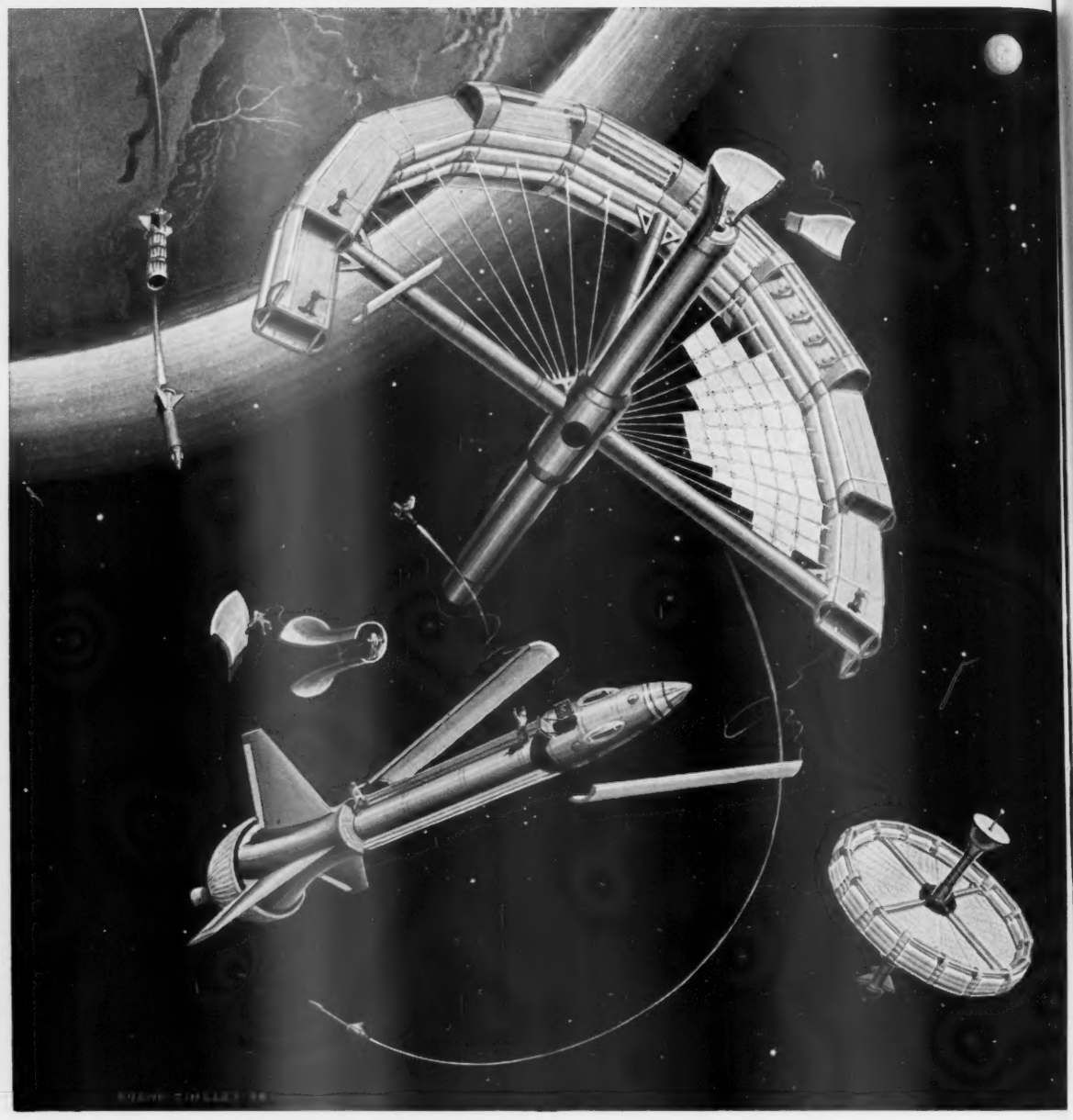
In this issue

Space • Ceramics • Navigation • Systems • Air Cargo • Education

President Wells on Institute Membership . . . . . *p. 33*

DECEMBER | 1958

XUM



STEPS IN THE RACE TO OUTER SPACE

Assembling a station in space

This imaginative but technically accurate illustration shows a permanent satellite (center) being constructed in orbit around the earth. It generates its own heat and electricity from solar rays. Basic vegetation (such as algae) for oxygen as well as protein-rich foods are grown in hydroponic tubes in upper level "greenhouses."

New vistas in astronomy will be opened up by such a space station, because of perfect conditions for photography and spectroscopy. It will also provide unique conditions for advanced research in physics, electronics, weather prediction, etc. Three such stations, properly placed, could blanket the entire world with nearly perfect TV transmission.

Atomic rocket vehicles with prefabricated skin layers (lower center) provide building materials for the station, then return (bottom) to earth. Similar craft will service an established station (lower right), docking by electromagnetic pull in lower section of station's axis.

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ARMA needs key men to augment a broad research program in missile guidance and space technology. As designer and developer of all-inertial navigation systems for TITAN and ATLAS ICBM's, ***ARMA*** provides a stimulating atmosphere where creative talents can develop. Write to E. C. Lester, Professional Placement, AE-1, ***ARMA*** Division, Garden City, N. Y. A Division of American Bosch Arma Corporation.

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Adaptable to any missile operation where mobility is vital, Goodyear Aircraft's complete ground support equipment moves swiftly and surely in deep snow, sand or mud—unhampered by weather extremes of from −65° to 125° F! This amazing mobility makes it possible to get out of the area fast once missile has been launched.

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Here is a major contribution—engineered by a leading team with firsthand understanding of the complete missile concept—a contribution of special importance when one considers that ground support has often run as high as 60% of total missile cost. Please write for details. This experience may solve your problem. Goodyear Aircraft Corporation, Dept. 916FX, Akron 15, Ohio.

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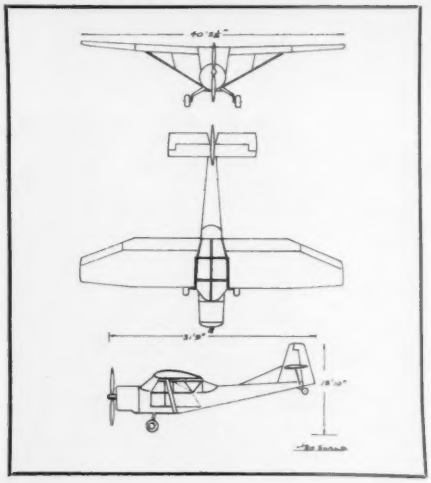

On our cover

. . . is the Centaur (3-view at left), a new single-engine utility plane designed to perform a variety of tasks from small and unimproved fields. The manufacturer, Longren Aircraft Co., Torrance, Calif., reports take-offs in 325 ft. (725 ft. to clear 50-ft. obstacle) and no unusual flight characteristics when carrying 1,800 lbs. of cargo. Normal cruise is 100 m.p.h. and stall occurs at 46 m.p.h. Maximum range is 850 miles. The Centaur's wings fold when required, and the aircraft, called "The Flying Workhorse," is powered by a Lycoming R-680, 300-hp. engine. The electrical system is 24-volt. Span is 40 ft. 5½ in.; length, 31 ft. 9 in.; height in flight position, 13 ft. 10 in.

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AERONAUTICAL ENGINEERING REVIEW

AERO/SPACE ENGINEERING

VOLUME 17 / NUMBER 12 December 1958

Featured in this issue

A Report **23** Flight Test Fellowship Grads—Where Are They Now?
What an IAS Flight Test Engineering Fellowship can mean to you.

Edward C. Wells, President, IAS **33** The Dual Responsibility of IAS Membership (Editorial)
A thought-provoking assessment of the IAS and how it may continue as a vital force in the future.

W. J. Knapp and F. R. Shanley, University of California **34** Ceramic Materials—Properties for Structural Applications
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Robert E. Roberson, North American Aviation, Inc. **39** Some Problems of Space Navigation
Seven are presented. First—there has been no comprehensive review of existing literature.

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"Current programs . . . are aimed at increasing the range of temperatures to 1,500°F. and higher. . . ."

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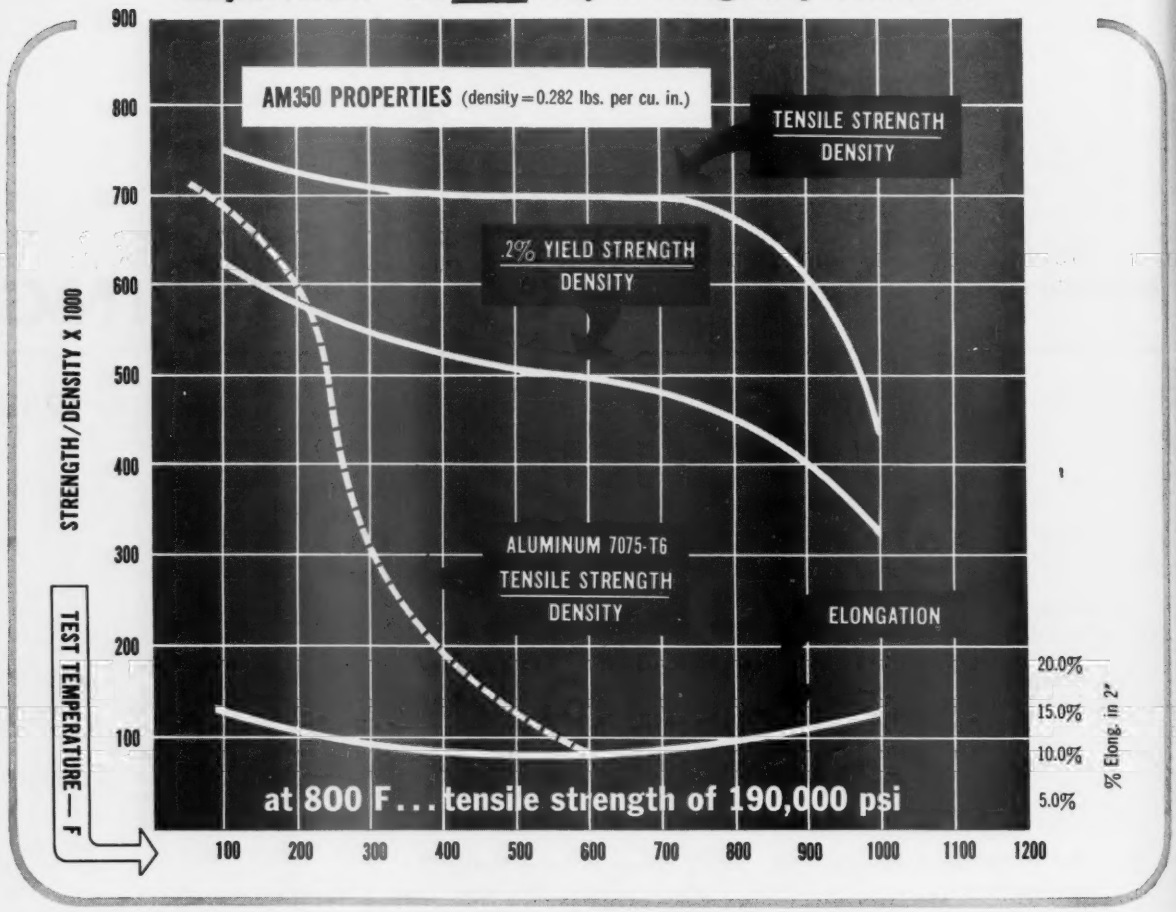

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A unique combination of highly desirable properties is the usual description of Allegheny Stainless AM350 and AM355 Steels. They combine high strength at both room and elevated temperatures, excellent corrosion resistance, ease of fabrication, low temperature heat treatment, good resistance to stress corrosion.

They are proving the answer to many problems of the air age. Airframe and other structural parts, pressure tanks, power plant components, high pressure ducting, etc. are all natural missile and supersonic aircraft applications for AM350 and AM355.

Availability: AM350, introduced several years ago, is available commercially in sheet, strip, foil, small bars and wire. AM355, best suited for heavier sections, is available in forgings, forging billets, plate, bar and wire.

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Easy fabrication: AM350 and AM355 can be spun, drawn, formed, machined and welded using similar procedures as with the 18-8 stainless types. In the hardened condition (SCT & DA) some forming may be done . . . 180 degree bend over a 3T radius pin. Also it can be dimpled in the hard condition to insure accurate fit-up.

For further information, see your A-L sales engineer or write for the booklet "Engineering Properties, AM350 and AM355." ***Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pa.*** Address Dept. AE-12.

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IAS News Notes

December 1958

1959 LEADERSHIP - William Littlewood, Vice President - Equipment Research, American Airlines, Inc., named American Honorary Fellow of the Institute for 1957, has been elected IAS President for 1959. He will take office at the Annual Meeting Honors Night Dinner at the Hotel Astor, New York City, on January 27th. Also elected by the Council were the following as Vice Presidents: Clifford C. Furnas, (F), Chancellor, University of Buffalo; Clarence L. Johnson, (F), Vice President - Research and Development, Lockheed Aircraft Corporation; I. Nevin Palley, (AF), Vice President - Engineering, Temco Aircraft Corporation; and Raymond C. Sebold, (F), Vice President - Engineering, Convair Division of General Dynamics Corporation. Jerome Lederer, (F), Director, Flight Safety Foundation, was elected Treasurer.

ANNUAL MEETING ADDENDUM - Since preparation of the Annual Meeting news report on Page 21 of this issue, planning has been completed for two additional technical sessions - Flight Testing, and Education, the latter in cooperation with the ASEE. Sessions now total 23.

THE INSTITUTE'S Director of Publications, Welman A. Shrader, has announced appointment of John Ball, Jr., as Director of Public Relations for the IAS, and Western Representative of Aero/Space Engineering. His offices are located in the IAS West Coast Building, 7660 Beverly Boulevard, Los Angeles 36, Calif. Telephone: WEbster 1-1841.

AERO/SPACE ENGINEERING will begin publication of another new monthly feature in January, when "Letters to the Editor" makes its debut, giving IAS members and other readers a voice in an especially-allocated area of the magazine for the first time. Views on matters technical will be particularly welcome, although no holds will be barred. Contributions cannot be acknowledged; all must be signed, but identities will be withheld on request.

PUBLICATIONS OF NOTE: Two publications which may hold special interest for IAS members in coming months are the Aero/Space Engineering Catalog for 1959, and the special Space Flight Issue of this magazine. The Catalog, with nearly 1,000 new headings added and otherwise brought up to date for greater service, is scheduled for publication in March. A/SE's Space Flight Issue will appear in April. It will supplant the special Electronics-Navigation-Guidance-Control issue which in former years has been published in May. The Space Flight Issue also will include these fields of interest.

SECTION MEETINGS CALENDAR

Dec. 3 — Baltimore: Dinner Meeting, The Martin Co., Middle River, Md. (Dinner at 6:30; classified meeting at 8.) "The ASW Problem in Free World Defense." Speaker, Rear Admiral John S. Thack, USN.

Dec. 3 — Philadelphia: Dinner Meeting, Penn-Sherwood Hotel, Philadelphia. (Dinner at 7; meeting at 8.) "Techniques of Aircraft Accident Investigation." Speaker, John F. Pahl.

Dec. 15 — Wichita: Dinner Meeting, Innes' Main Dining Room, Wichita. (Social hour at 6:30; dinner at 7; meeting at 8.) "Fifty-Five Years After the Wright Brothers--A Look Into the Future." Speaker, IAS President Edward C. Wells.

Dec. 16 — Boston: Specialist Meeting, Massachusetts Institute of Technology, 8 p.m. "Personal Observations of Soviet Engineering." Speaker, Professor Leon Trilling.

Dec. 18 — San Francisco: Dinner Meeting, Ramor Oaks Restaurant, Atherton, 8 p.m. "Recent Developments in Ramjets." Speaker, E. Perchonok.

Dec. 19 — Texas: Dinner Meeting, Carter Field. (Social hour at 7; dinner at 8.) Wright Brothers Lecture on French aeronautical research. Speaker, Maurice Roy.

JOINT MEETINGS CALENDAR

Apr. 5-10 — 1959 Nuclear Congress, Municipal Auditorium, Cleveland.

May 25-27 — National Telemetering Conference, Cosmopolitan Hotel, Denver. Sponsored by IAS, ARS, ISA, and AIEE. Theme, "Investigation of Space."

June 11-13 — 1959 Heat Transfer and Fluid Mechanics Institute, University of California, Los Angeles. Cosponsored by IAS.

NATIONAL MEETINGS CALENDAR

Dec. 17 — Wright Brothers Lecture, Natural History Building Auditorium, Smithsonian Institution, Washington, D. C. French aeronautical research will be discussed by Maurice Roy.

1959

Jan. 26-29 — Twenty-Seventh Annual Meeting, Astor Hotel, New York. Honors Night Dinner, Tuesday, January 27.

Mar. 5-6 — Flight Propulsion Meeting, (Classified), Hotel Carter, Cleveland.

June 16-19 — National Summer Meeting, Los Angeles, California.

Oct. 29-31 — National Midwestern Meeting, Wichita, Kansas.

INTERNATIONAL MEETINGS CALENDAR

1959

Oct. 5-16 — Seventh Anglo - American Aeronautical Conference, New York.

* * * * * * *

IAS News

. . . a record of people and events of interest to Institute Members

IAS Annual Meeting to Serve Interests in 21 Aero/Space Fields

ENGINEERING interests in 21 specific aeronautical and space fields, and many branches, will be served at the IAS 27th Annual Meeting at the Hotel Astor, New York, on January 26–29, 1959. T. Keith Glennan, NASA Administrator, will be guest speaker at the Honors Night Dinner on Jan. 27.

Edward C. Wells, retiring IAS President, will be Toastmaster at the Dinner and will present the John Jeffries, Robert M. Losey, Sylvanus Albert Reed, Lawrence Sperry, and Grover E. Bell awards. He also will name those elected to Honorary Fellowships and Fellowships, both American and non-American, for 1958.

Programs listing the sessions, all papers to be presented and their authors, and other pertinent data in detail will be mailed individually to IAS members.

Again anticipating trends in the steady advance of aero/space research and development, IAS Annual Meeting planners have scheduled sessions as outlined below. (Readers are referred to the official program for complete information. Chairmen are identified herein only if their acceptances of IAS invitations have been received at this writing.)

Space Exploration

There will be three sessions and one discussion—general in nature—on this topic. *Chairmen:* Prof. Charles S. Draper, of M.I.T.; Prof. Courtland D. Perkins, of Princeton; and Brig. Gen. Don Flickinger, USAF (MC).

Propulsion

Two sessions are being arranged.

Structures

Chairmen of two sessions on this subject are Samuel Levy, Missile and Ordnance Systems Dept., General Electric Co.; and Prof. E. E. Sechler, of C.I.T.

Aerodynamics

There will be four sessions in this field. *Chairmanships* have been accepted by Prof. Lester Lees, of C.I.T.; and Galen B. Schubauer, of the National Bureau of Standards.

Management

One session. *Chairman:* Edward A. Ledeen, of Wright Aeronautical Division, Curtiss-Wright Corp.

T. Keith Glennan

Supersonic Jet Transports

One session. *Chairman:* R. Dixon Speas, of R. Dixon Speas Associates.

Air Transportation (All Weather)

One session. *Chairman:* David S. Little, of American Airlines, Inc.

STOL/VTOL

Jointly with AHS. One session. *Chairman:* Col. Michael Strok, USA.

Rotary Wing Aircraft

Jointly with AHS. One session. *Chairman:* Charles M. Seibel, of The Cessna Aircraft Co.

Meteorology

Jointly with AMS. One session. *Chairman:* Prof. Sverre Petterssen, University of Chicago.

Aeroelasticity

One session. *Chairman:* Holt Ashley, of M.I.T.

Balloons

In cooperation with ONR. Two sessions. *Chairmen:* D. H. Menzel, Harvard Observatory; and Capt. N. L. Barr, USN.

Nine IAS Members Staff NASA Posts

The National Aeronautics and Space Administration, like its predecessor NACA, boasts a host of IAS members in top posts.

Hugh L. Dryden (HF), former NACA Director, is NASA Deputy Administrator.

Abe Silverstein (F) has been appointed Director of Space Flight Development. He also is a member of this magazine's Flight Propulsion Editorial Advisory Committee.

Abraham Hyatt (AF), former BuAer Chief Scientist and Research & Analysis Officer, has been appointed Assistant Director for Propulsion.

Other IAS members and their NASA jobs are John W. Crowley, Jr. (F), Director, Aeronautical and Space Research; Newall Sanders (AF), Assistant Director for Advanced Technology; Ira H. Abbott (F), Associate Director, Aerodynamics and Space Mechanics; Addison M. Rothrock (F), Associate Director, Propulsion; and Richard V. Rhode (F), Associate Director, Materials, Structures, Loads, and Operating Problems.

John F. Victory (M), NACA Executive Secretary, was appointed Assistant to Administrator T. Keith Glennan.

Benford to Head Medical Agency

Colonel Robert J. Benford, USAF (MC), a member of this magazine's Editorial Advisory Committee Specialties Panel, has been named Director of the Armed Forces Medical Publication Agency and Editor, *U. S. Armed Forces Medical Journal*.

Since 1955, Colonel Benford has been Editor of the *Journal of Aviation Medicine*, official publication of the Aero Medical Association. He was Staff Surgeon, 20th Bomber Command during World War II.

AC Spark Plug Division Is New Corporate Member

AC Spark Plug Division, General Motors Corp., has joined the IAS as a Corporate Member. Headquarters for the division is in Flint, Mich.

Founded in 1908, it is one of GM's major divisions and has one of the largest and most diverse engineering groups in the corporation. It produces automotive, aircraft, and marine accessories and has an electronic engineering and production organization as well. Most of AC's military, electronic, and gyroscope operations are centered in Milwaukee, Wis.

(*Continued on page 27*)

privacy and creativity

Privacy, meditative thought, ideas. These are the pillars of the house called creativity.

Mindful of the requisites for resultful thinking, the Hughes Research & Development Laboratories provide all engineers with either private or semi-private offices.

With this emphasis on privacy, searching minds are able to probe the vastly complex problems associated with advanced electronics.

If you are capable of making significant advances to the state of the art...if you demand privacy...if you search for plentiful intellectual and monetary reward... write directly to: Dr. Allen Puckett, Associate Director, Systems Development Laboratories, Hughes Aircraft Company, Culver City 30, California.

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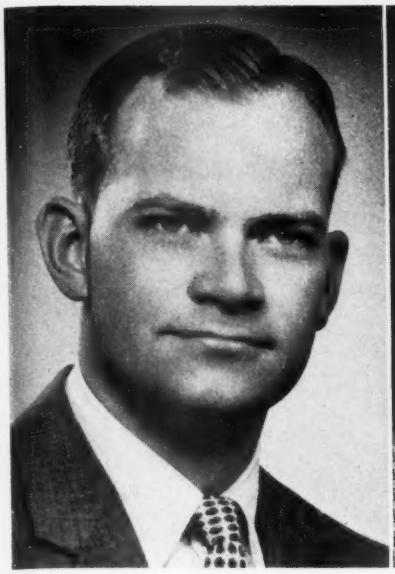
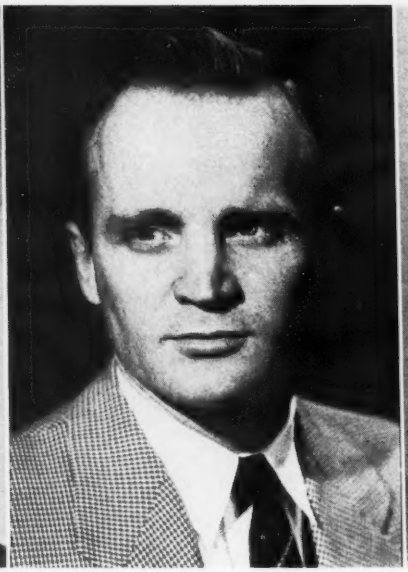
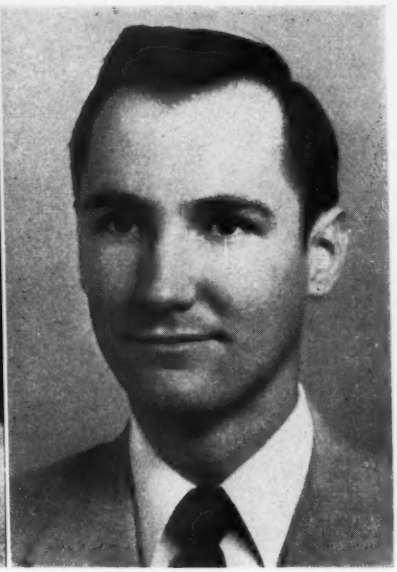


David G. Powell



Warren J. North



William B. Browne

Flight Test Fellowship Grads—

Where Are They Now?

INCREASED knowledge, greater professional ability, broader vision, and eligibility for positions of significant responsibility—these are a few of the advantages which come to the IAS Flight Test Engineering Fellows. Of the three who have completed their course of study at Princeton (two others are still on campus), one is now a Research Aerodynamicist, one a Missile Design Specialist, and the other a Vanguard engineer. All agree the IAS Fellowship has been a valuable asset to their careers.

David G. Powell, first to receive the IAS Fellowship (1954) is a Research Engineer at Lockheed's California Division. Mr. Powell has said that "after the first year [at Lockheed] I was assigned to the Research Group as an aerodynamicist. My work here consists of performance and stability analyses of preliminary designs and the development of current Lockheed aircraft, as well as research projects.

"In working with current aircraft, my flight test training is of paramount value, since many of our aircraft are now going through flight test development.

"All of my graduate course study and thesis experience have been of direct use in the present assignment."

Warren J. North was recently assigned to a Missile Design Panel at the NASA Lewis Research Center in Cleveland. When he was Assistant Chief, Aerodynamic Noise Research Branch at Lewis, Mr. North wrote as follows: "...I have realized how fortunate I was to have had the opportunity to study at Princeton.

"I have written a report on aircraft dynamic stability using theory acquired at Princeton. Currently, in addition to work on aerodynamic noise research, I am using electronic computers to investigate several new aspects of dynamic stability for high-performance airplanes.

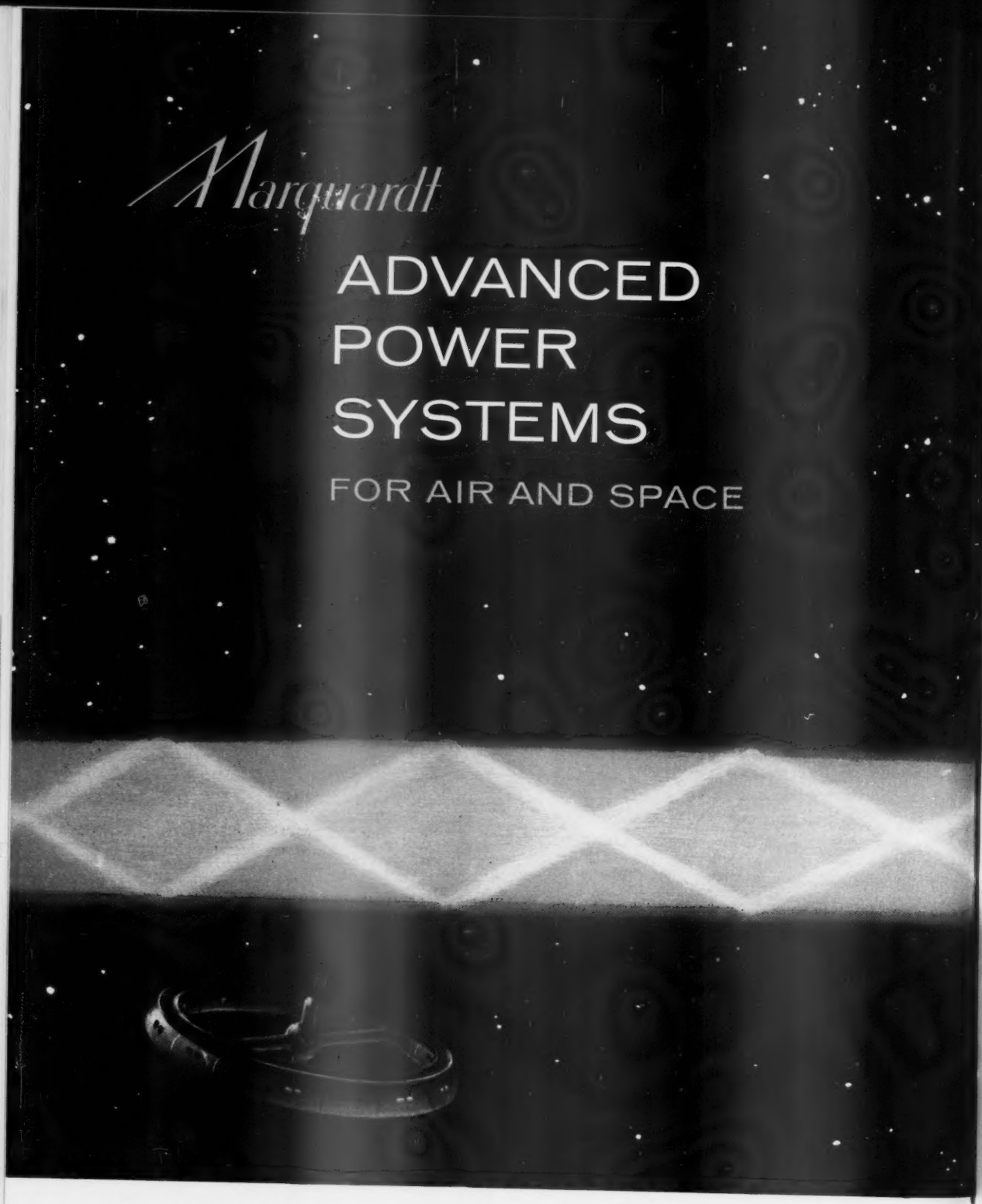
"One gratifying aspect of the Fellowship tour was the enjoyment my wife and children realized. They talk often of our Princeton friends and neighbors."

William B. Browne worked as an Aerodynamics Engineer with the Martin Company in Baltimore after his studies at Princeton. He has described his Fellowship as having played a "very valuable" role in his work with trajectory optimization and range safety studies connected with Project Vanguard. He is currently assigned to a highly classified project for the Martin Co.

Franklin F. Eckhart, another Fellowship winner who began his second year of study last September, wrote to the IAS recently, outlining his curriculum and adding that "I have continued my military flying in the Naval Air Reserve...at Lakehurst, N.J.

"This past semester has really been quite challenging, mainly because I had to readjust to a rigorous academic schedule." (Mr. Eckhart was previously a Navy jet pilot.) "Now that I have made that adjustment, I am eagerly looking forward to the [next] semester."

If you are interested in the IAS Flight Test Engineering Fellowship, you may apply for the 1959 Award, provided you will have received your Bachelor's Degree by June of next year and you are a U.S. citizen. Details regarding the Fellowship (total award, $7,300) and applications may be obtained by writing a brief letter, endorsed by a sponsoring reference, to: Flight Test, IAS, 2 East 64th St., New York 21, N.Y. All application forms must be received before March 1, 1959.



Projects meeting the ever increasing needs of Advanced Power Systems for Air and Space operations are currently under way at Marquardt. Here, in an environment that stimulates creative hypotheses, Marquardt engineers and scientists are engaged in the following diversified areas:

ADVANCED PROPULSION CYCLES

- Ramjets for cruise propulsion for hyper-velocity missiles and piloted aircraft and as accelerating devices for Space Vehicles
- Electrical Propulsion—Plasma Jets, Ion Propulsion and Magnetohydrodynamics
- Nuclear Ramjet

EXOTIC FUELS

- Evaluation—Energy, Compatibility and Logistics

CONTROLS & ACCESSORIES

- Hot Gas Servo Systems
- Accessory power for Space application
- Variable geometry Inlet Controls

In addition, current application projects include supersonic ramjet power for Bomarc, Super Bomarc, X-7 (test vehicle), Q-5, and Kingfisher.

XUM

(*Continued from page 21*)

AC is producing inertial guidance systems for the Thor and is developing systems for the Regulus and Mace missiles. The division also is active in the development of bombing navigational computers, sights, and jet-engine fuel controls.

Jospeh A. Anderson, a GM Vice-President, is General Manager of the division. Martin J. Caserio is Manager of its Milwaukee operations.

New Manual Sent to Student Branches

A new *Student Branch Manual*, illustrated with bright cartoons, has been published and distributed by the IAS to all Branch officers and Faculty Advisers.

Ideas which have made Student Branches successful have been gathered together in the 1958 revised edition. The *Manual* tells with story and pictures how the Branch is established, how it functions, and how it benefits student members.

The student's role in the IAS is discussed in the introduction, along with the Institute's place in the aero/space industry. There also is a section devoted to Branch rules and by-laws.

The purpose of the *Manual* is to outline Branch operations and to serve as a reference guide for the administration of Branch business.

Student Conferences Add Doctoral Division

Another division in which doctoral candidates may compete separately has been added to the IAS Regional Student Conferences. The 1959 competition will include Undergraduate Division, Master's Division, and Doctorate Division prizes.

The announcement was made in a new booklet, *Ground Rules*, published for those responsible for conference planning and operation. The booklet organizes procedure for all conferences to ensure equitable financial assistance from the Minta Martin Aeronautical Student Fund. It also provides aids for better coordination between conference sponsors and IAS National Headquarters.

Ground Rules has been mailed to Student Branch Faculty Advisers and Conference Hosts.

Heat Transfer Institute Scheduled for Los Angeles

The 1959 Heat Transfer and Fluid Mechanics Institute will take place at the University of California, Los Angeles, June 11–13. It will provide an opportunity for authoritative discussion of fundamental ideas at an early stage of their development.

Emphasis will be placed on consideration of thermal phenomena, chemical reactions, electromagnetic fields, thermal radiations, and low pressures.

Original technical papers scheduled will be preprinted in full, and copies will be mailed to preregistered participants 3 weeks before the meeting.

The following officers are in charge of the meeting: General Chairman, E. L. Knuth, Department of Engineering, University of California; Committee Chairman, *Papers*, A. Mager, Marquardt Aircraft, and E. Meyer, Rocketdyne; *Program*, D. Masson, RAND Corp.; and *Arrangements*, J. C. Dillon, University of California.

Donald W. Douglas, Sr. (HF), has been awarded The Franklin Institute's Franklin Medal for "his creative engineering in the field of aeronautical design...particularly [for] the DC series of transport airplanes...and in recognition of his engineering genius which has provided inspired leadership for the technical developments of his industrial organization." Thomas Edison was first recipient of the medal in 1915.

Brig. Gen. H. F. Gregory, USAF (AF), retired from the Air Force on October 31. He had been Commander, Air Force Office of Scientific Research, Air Research and Development Command.

IAS *News* — *News of Members*

Lee Arnold (AF) has been named Professor and Chairman of the Department of Aeronautical Engineering, and Director, Guggenheim School of Aeronautics at New York University. He formerly was Professor, Institute of Flight Structures, Columbia University.

Donald C. Berkey (M) has been named General Manager, Jet Engine Department, in General Electric's Aircraft Gas Turbine Division. He formerly was Manager, Applied Research Operation, Flight Propulsion Laboratory Department.

E. Arthur Bonney (M), former head, Aerodynamics Group at Johns Hopkins Applied Physics Laboratory, entered Gordon Divinity School, Beverly Farms, Mass., in September.

Richard H. Brown (A) has become a member of the Defense Research Staff, Massachusetts Institute of Technology Instrumentation Laboratory. He formerly was with the Southern California Cooperative Wind Tunnel, California Institute of Technology.

Robert H. Dufort (M) has joined Cornell Aeronautical Laboratory, Inc., as Principal Aeronautical Engineer, Systems Synthesis Department. He formerly was Project Engineer, Rockets Division, Bell Aircraft Corp.

Harry E. Emlet, Jr. (A), has joined Analytic Services, Inc., as Research Analyst. He had held the same position with Covey Division of Melpar, Inc.

Andrew A. Fejer (AF) has been named Director, Mechanical Engineering Department, Illinois Institute of Technology. He formerly was Chairman, Department of Mechanical Engineering, University of Toledo.

D. R. Gero (AF) has been appointed to the position of Vice-President and General Sales Manager, G. M. Giannini & Co., Inc. He moves up from Vice-President, West Coast Avionic Divisions.

Everard M. Lester (AF) has been appointed General Manager, Engine Division, Fairchild Engine and Airplane Corp. He had been Assistant General Manager of the Division since 1951.

Wilbur C. Nelson (AF) has been reappointed Chairman, Department of Aeronautical Engineering, for a period of 5 years. He has been Chairman of the Department since 1953.

XUM

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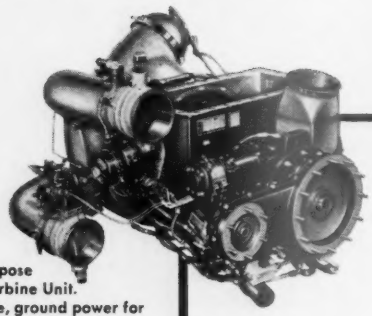

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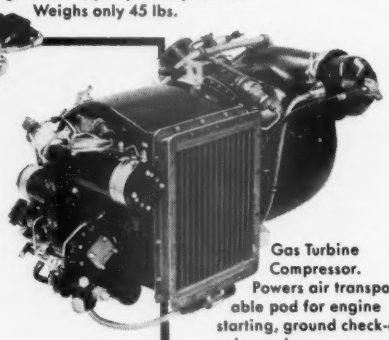

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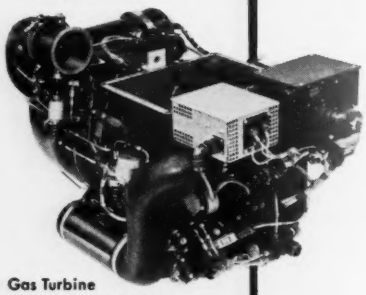
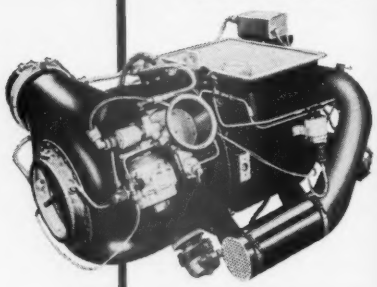
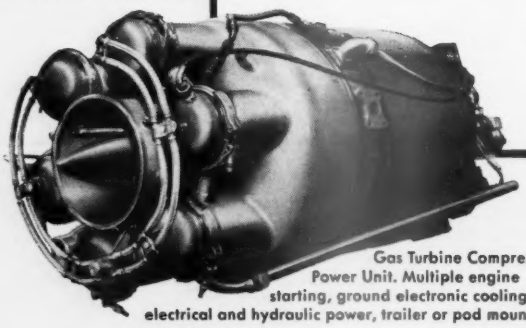


Gas Turbine Compressor. Standby in-flight pneumatic power for turbine-powered transports.



Gas Turbine Compressor Power Unit. Electrical and pneumatic ground power source for jet transports.



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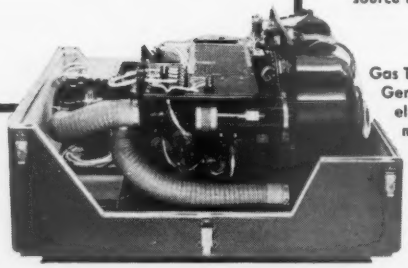

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Gerhard Neumann (M) has been named General Manager, Small Aircraft Engine Department, in General Electric's Aircraft Gas Turbine Division. He formerly was General Manager, Jet Engine Department.

Claude F. Riley, Jr. (M), has joined Spencer Stuart & Associates, Inc., as a member of its Chicago headquarters Staff. He formerly was an Associate in Booz, Allen & Hamilton.

Anatol Roshko (AF) has been promoted from Assistant Professor to Associate Professor at California Institute of Technology.

Harner Selvidge (M), Staff Engineer, Bendix Aviation Corp., has been elected President of the Soaring Society of America.

Martin Schilling (M) has been appointed Programs Manager and Director, Advanced Development, at Raytheon's Missile Systems Division. He had been Chief, Projects Management Staff, R&D Division, Army Ordnance Missile Laboratories.

Murry Schoenberger (A) has joined the Naval Air Test Facility, Lakehurst NAS, N.J., as Aeronautical Structural Development Engineer. He formerly was affiliated with Fairchild Engine and Aircraft Corp. as Stress Engineer, Fairchild Aircraft Division.

Richard A. Schram (AF) has joined Chicago Aerial Industries as Director of Public Relations. He formerly was Assistant Sales Manager, Shafer Bearing Division, Chain Belt Co.

Paul A. Schweizer (M), Vice-President and General Manager, Schweizer Aircraft, has been elected a Vice-President of the Soaring Society of America.

Guy C. Shafer (M), formerly General Manager, General Electric's Small Aircraft Engine Department, has been assigned to a special task force on the Electronic Aids to Industrial Management Project for G-E.

Sir Geoffrey I. Taylor (HF), former Yarrow Research Professor of The Royal Society of London, has been awarded the ASME Timoshenko Medal for "his many fundamental contributions to a better understanding of the mechanics of solids and fluids."

Milton D. Van Dyke (A) has become visiting professor in the Faculty of Sciences, University of Paris, during the 1958–1959 academic year. He is on leave from the NASA Ames Research Center.

Theodore von Kármán (HF), AGARD Chairman, has been awarded the ASME Timoshenko Medal for "his contribution to the mechanics of fluids and solids, particularly those leading to major advancements in aeronautics."

Maurice A. Walter (M) has been appointed Manager, Contracts Services, in the Subsystems Division of Servomechanisms, Inc. He formerly was Chief, Engineering Services.

(IAS News Continued on page 103)

Necrology

B. W. Ainsworth

The Institute has learned of the death of B. W. Ainsworth (A), former Assistant to the General Manager, Sikorsky Aircraft Division, United Aircraft Corp. He was 72.

Mr. Ainsworth was educated in English schools and, when World War I began, was studying engineering at London University. Between 1914 and 1918 he served as a member of the British War Mission to the United States as a Lieutenant in the Royal Army Service Corps and Engineering Specialist and Inspector of Mechanical Transport.

After the war he worked for the Locomobile Co. in various managerial posts. He held a succession of jobs in the automotive field: Vice-President of Rolls-Royce of America and Vice-President and General Manager, Brewster Co., including its Aviation Division.

With the late Comdr. James B. Taylor, Jr., he founded (1934) Taylor-Ainsworth, Inc., test pilots and aviation consultants, with which he served as Vice-President and Treasurer. In 1940 he joined the Gray Manufacturing Co. as Executive Vice-President, and in 1942 he joined Sikorsky.

Besides his membership in the IAS, he was also a member of the Wings Club and the Institute of Automobile Engineers (England).

John C. Fowler

The IAS has learned of the death on November 3, 1957, of John C. Fowler (A), owner of Fowler Aero Service, Burbank, Calif. He was 44.

A graduate of Los Angeles City College, Mr. Fowler began his career in aviation with the Pan-American Navigation Service in 1942. As Chief Instructor, he was in charge of training programs, instructors, students, materials, and policies.

Mr. Fowler was born in Des Moines, Iowa, in 1913. He was also a member of the Institute of Navigation.

John L. Genta

Commander John L. Genta, USN (A), was killed by lightning on August 1. He was 40 years old.

Commander Genta attended Blackburn College, Carlinville, Ill., the University of Illinois, and Massachusetts Institute of Technology.

He became a Naval Aviation Cadet in 1940 and was assigned to the Pacific Fleet during World War II. He was head of the Department of Test Flight and Inspection, NAS Beaufort, S.C., from July, 1944, to February, 1945.

Commander Genta held a commercial pilot multiengine land and sea license and was holder of the Air Medal.

Harold P. Henning

Harold P. Henning (M), Operations Manager, General Motors Air Transport Section, died on September 12 after a long illness. He was 57.

Mr. Henning began flying in 1922 while a civil engineer in highway maintenance and construction at Santa Fe, N.M. He barnstormed throughout the Southwest for a year before getting into the aerial and ground mapping business in 1926.

The following year, he organized and operated an aerial mapping and engineering service company, selling services to oil producing and pipe-line companies and transmission line, highway, and taxation projects.

Between 1929 and 1935, he was employed in the aviation department of The Texas Co. where he assisted in the development and flight testing of aviation petroleum products. He also worked in sales and advisory capacities contacting airline, manufacturing, and operating companies.

He established and operated (as General Manager) the Booth-Henning Co. at Dallas, Tex., in 1935. He built a complete engine and aircraft overhaul base, the first equipped to handle every type of aircraft then flying with CAA-approved airframe, engine, propeller, instrument, accessory, and radio shops.

In 1939 he sold his interest in this business and went to work for Stinson Aircraft as Division Sales Manager.

Upon recommendation of James H. Doolittle, Mr. Henning was employed by the Ford Motor Co. in July, 1941. He supervised the layout and construction of Willow Run Airport, including all fixed installations. He organized flight operations and had responsibility for testing of all aircraft after they left the assembly line. He selected the firm's nucleus of pilots, flight engineers, and mechanics and personally piloted the first production B-24 at Willow Run.

Mr. Henning also established a flight research program for high-altitude tests on the R-2800 engine ignition development and participated in extreme altitude tests in decompression and cold chambers. He also flew nearly every type of U.S. military aircraft then current.

He joined Bell Aircraft in 1944 as Assistant Manager of Flight Research, a job that involved test flying and direction of departmental activities.

He was also a member of the National Aeronautic Association, Fédération Aéronautique Internationale, and Quiet Birdmen.

John J. Herfurth

The IAS has learned of the death of John J. Herfurth (M), an Aerodynamics Engineer in Douglas Aircraft Company's Aerodynamics Section.

Mr. Herfurth was born in Milwaukee, Wis., September 29, 1928. He held a Bachelor of Aeronautical Engineering degree and an M.S. in Aeronautical Engineering, both from the University of Minnesota where he studied from 1946 to 1951.

Mr. Herfurth had been a Student Member of the Institute.

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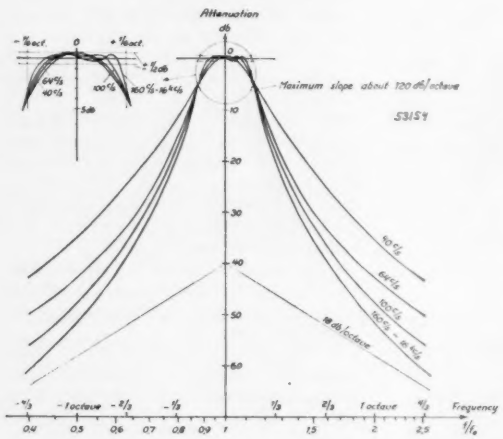

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Thirty ⅓ octave band filters are used in the Model 2110 to extend the frequency range for complex signal analysis to be from 35 c/s to 36,000 c/s. Optional ⅓ octave filters may be added to extend the low frequency range down to 14 c/s. These are available as a separate unit Model 1619 and may be plugged directly into a front panel jack on the Model 2110.

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DATELINE World

PROFESSIONAL NOTES AND REPORTS

Engineering and Scientific Briefs from Correspondents Around the Globe

U.S.S.R. General, Engineer Views Utility of Aero/Space Vehicles

◆ In the Soviet monthly journal *Herald of the Air Fleet*, January, 1958, Prof. G. I. Pokrovskiy, a major general of the Engineering and Technical Service, has written an article titled "From Aerodynamic Flight to Space Flight." Pokrovskiy identifies the terrestrial-bound atmosphere as comprising three "zones" from the standpoint of flight conditions—lower, middle (or transitional), and upper (or space equivalent). The middle zone, he states, ranges from 20 to 120 miles thick, and, while prolonged flight in this zone is not feasible, space vehicles must traverse it. To do so, Pokrovskiy suggests that a speed not exceeding Mach 3 will be found most advantageous in order to avoid excessive aerodynamic heating in the transitional zone.

Pokrovskiy devotes considerable attention to expressing formulas showing the relationship of space-flight velocity to lift and centrifugal forces. Thus, he finds that orbital velocity can be written approximately as $V_o = \sqrt{g/(R + H)}$, assuming a uniform gravitational field, where R is the earth's radius, H is orbital altitude, and g is acceleration due to gravity. (Using this formula, we find that the orbital velocity of a satellite 200 miles high would be approximately 17,300 m.p.h.)

Except for a brief discussion of aerodynamic heating zones at altitude, the remainder of the article dealt with the energy requirements for orbital space vehicles. Pokrovskiy illustrates this aspect effectively by use of a comparison. Assume that it is desired to deliver a load by aircraft a distance of 8,000 nautical miles at a speed somewhat in excess of Mach 1. Then, since the effective engine thrust will approximately equal the aircraft weight, 48.6 million ft.lbs. of work will be expended for each pound of aircraft total weight over the distance covered. This is a great deal of energy.

The situation is different, Pokrovskiy continues, with regard to space flight since energy is expended only to lift the vehicle to a given altitude and accelerate it to orbital or escape velocity. Thus, approximately one-half million pounds of work are required to lift one pound to an altitude of 100 miles. In addition, assume that a velocity of 26,000 ft./sec. is imparted to the vehicle. The latter requires an energy input of 10.5 million ft.lbs.; thus, the total energy for such a flight would be approximately 11 million ft.lbs. Pokrovskiy concludes that space flight is, therefore, approximately 4.4 times more "economical" than the high-speed flight of aircraft and about 20 times faster. In a further derivation, he states that the energy required for space flight, per unit weight, is approximately $E = (1/2)R$, where R is the earth's radius, as before.

While Pokrovskiy's presentation is interesting and thought-provoking, it contains nothing essentially new. It is worth noting that the author, in evaluating spacecraft as much more efficient than aircraft, does not concede a more obvious factor—that of cost, which for some time to come will heavily favor the aircraft.

This article is of interest because of its comparison of the "utilization" aspects of (manned) space-flight vehicles with manned aircraft flight, as viewed by a prominent Soviet engineer, docent, and military personage. Apparently Major Gen. Pokrovskiy and others of his service and professional stature are writing articles of this type periodically in Soviet service publications to furnish increased lay comprehension of space-flight concepts.

New Extrusion Concept Solves "Core" Problem

◆ The August, 1957, issue of *Tsvetnye Metally* (*Nonferrous Metals*) describes a new Soviet concept in extrusion which has been developed to solve the problem of "piping" or "core" formation.

The appearance of the "core" defect is that of oxide in the center of extruded rod and results from the type of flow in the extrusion container whereby the extrusion of the original billet becomes the center of the extrusion. This defect is common in the extrusion of brass rod.

The cause of the defect has been studied in the United States for approximately 30 years and is attributed to turbulent rather than lamellar flow, arising from friction conditions in the extrusion container. As far as is known, no practical remedy has been found in the U.S. Indirect or reverse extrusion has been suggested in order to prevent relative motion between the billet and the container. It appears, however, that, while reverse extrusion is a solution, mechanical design of a press suitable for this operation is a difficult and complicated problem.

The described Soviet concept alleviates the difficulties associated with indirect extrusion while maintaining the fundamental simplicity of the process. The concept is based on the use of a movable container liner, positioned between the container and billet, which is pushed by the ram during the extrusion operation. The liner is half the length of the container, and in diameter is slightly larger than the die, in order to shear off the outer surface of the billet. With the movable container, the die moves relative to the billet, but the billet does not move relative to its container. Lamellar flow can thus take place with consequent elimination of the extrusion defect.

The successful development of this concept is a definite indication of Soviet ability to advance the "state of the art" in extrusion technology.

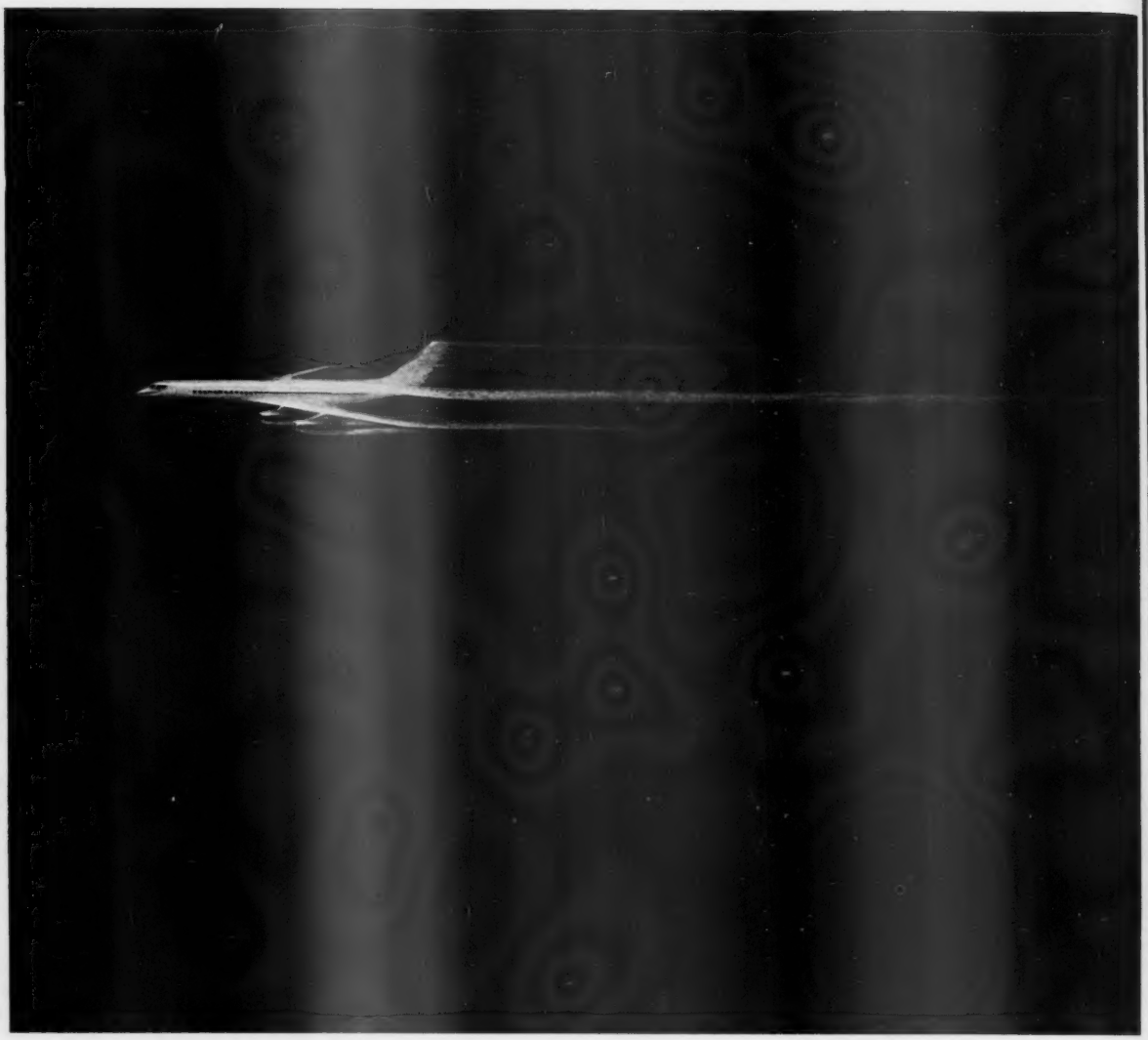
May Launching Scheduled for "Sputnik Skyscraper"

◆ The Soviets have set the month of May, 1959, as the date for launching the first "sputnik skyscraper," according to the Swiss newspaper *Basler Nachrichten*. The item states that the oval, cucumber-shaped space station will revolve in its orbit at 4,000 km. altitude, will measure 330 m. in length, and have a maximum diameter of about 85 m.

One-hundred and fifty transport sputniks are now under construction, it is reported. They will place in the chosen orbit both the materials necessary for the construction of the supersputnik, which will be constructed on the spot, and 75 "working cabins" necessary for assembling the supersputnik. The research on these cabins is already completed, according to the release.

Professor Blagonravov is credited with the statement that the problem of returning the space workers to earth has been solved. No worker will remain on the job more than 5 days. The regular crew for the completed "skyscraper" will consist of five men and will be relieved every 8 weeks by means of round-trip rockets.

Scientists from all countries will be invited in groups of five to visit the "sputnik skyscraper," named Robot I.



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GUEST EDITORIAL

The Dual Responsibility of IAS Membership

By Edward C. Wells
President, IAS

THE FOUNDERS of the IAS in their wisdom and vision gave to us, today's members, two important responsibilities, one stated and one implicit in the founding of such a society.

Our stated responsibility is that contained within our constitution, a clear responsibility to carry out the objective of the founders to the best of our ability. This objective is simply stated: "To advance the arts and sciences of aeronautics."

Our second responsibility, though not spelled out, is perhaps even more important to the future. This second duty is to recognize that, in the aeronautical sciences, change has been and ever will be the one certain element. In giving recognition to this fact, it is equally important that we realize that changes most certainly will take place not only within each of our engineering and scientific fields of specialization but in the general scope of the aeronautical sciences, with entirely new fields perhaps assuming roles of major importance.

I am sure that most of us as individual engineers, scientists, and managers have become increasingly aware of the changing times and that each of us as an individual has taken both thought and action to meet the new challenges ahead. If individual thought and action could suffice, there would be little purpose served by engineering and scientific societies, except perhaps a social function. We know from experience, however, that individual thought and action are stimulated by association and communication and that such societies—whether they be highly specialized or, like the Institute of the Aeronautical Sciences, broad in scope—serve to advance the competence and understanding of the individual and at the same time add to our total understanding of the universe.

Now I believe firmly that there is an important mission to be carried out by the specialized societies and an equally important mission to be carried out by societies such as the IAS. Those whose primary interest is in a specialized field can perhaps find the maximum of intellectual stimulation of an engineering or scientific nature only in an organization that includes primarily individuals of similar training and interests. There is a need, however, for ever-improving communication among and between these specialties as applied to a broad field of endeavor such as the aero/space sciences, and it is in this area that the Institute of the Aeronautical Sciences has been and should continue to be a vital force.

Speaking as an individual, as well as President of the IAS, I believe that it is in our separate and collective interest to be certain that our organization continues to develop on the broad front already established. In this manner, and only thus, will it adequately serve its members and effectively advance the aeronautical sciences as they can be visualized for the future. If this is our mission, and I sincerely believe that it is, how should we go about it?

Well, first, it should be stated that progress is not the responsibility of a limited segment of our organization. Your officers can provide leadership, your staff can provide effective execution, and we as members can provide direction—but all are required to do the job. Much has been accomplished by joint action of officers, staff, and members; much remains to be accomplished.

In our meeting program, full recognition has been given to the increased pace and scope of engineering and scientific activity. In membership, we are continuing to grow, due in no small measure to increased recognition and encouragement of student chapter activities. It is perhaps in this area of membership growth, which includes both numerical growth and growth in multiplicity of interests, that we may have the greatest cause for both gratification and concern.

Our concern should be focused on two facets of this

(*Continued on page 38*)

Mr. Wells is Vice-President - General Manager, Systems Management Office, Boeing Airplane Co.

Elevated temperatures now make impractical the use of common structural materials in certain parts of aircraft, gas turbines, and rocket engines. A solution is the use of ceramics.

Ceramic Materials— Properties for Structural Applications

W. J. Knapp and F. R. Shanley
University of California

THE DEVELOPMENTS in recent years in engineering and technology indicate a growing use of ceramics as structural elements. The familiar applications of ceramics in the construction of buildings, conduits, and sewer lines are being made at an increasing rate. In addition, new technological programs are producing environments wherein the commonly used structural metals are subjected to detrimental conditions (such as those of elevated temperatures and corrosion); as a result, the possibilities in using ceramics in these structural applications are receiving full consideration. A few of the many examples of new possible uses of ceramics are certain areas of aircraft structures where considerable aerodynamic heating is developed and the high-temperature zones of gas-turbine and rocket engines. The general purpose of this paper, therefore, is to examine the properties of ceramics pertinent to their general use as structural elements in both civil construction and special systems.

Some Physical Properties of Ceramics

Several of the obvious and desirable characteristics of ceramics for structural uses may be mentioned briefly; one is their resistance to corrosion at both normal and high temperatures. The ability to develop surface finishes with good architectural appeal is of considerable value for building construction. The abundant supply and worldwide occurrence of raw materials for manufacturing ceramic products is one of the most advantageous aspects of their use.

The following properties of ceramics are of particular interest in connection with their application as structural elements.

(1) Deformation Under Load

In general, most solid, crystalline materials exhibit both elastic and inelastic (plastic) deformations when subjected to loading. Ceramic materials offer no exception to this behavior, but the extent of development of elastic and inelastic deformations with changes in temperatures, stress, and time may be quite different from the results given by metals.

Deformation of Ceramics at Room Temperature—When loaded normally at room temperature, most crystalline ceramic materials exhibit essentially elastic deformation only to the point of failure. For example, Fig. 1 shows the stress-strain relation for sintered magnesium oxide at room temperature (see the curve designated 25°C.). These results, and others for various ceramics, indicate essentially elastic behavior for simple mechanical loadings at room temperature. In Table 1 are given some values for the elastic modulus of several typical ceramic materials. The rather wide range of values for the elastic modulus is apparent. Although very little study has been made of the creep characteristics of ceramics at room temperature, it is anticipated that such creep deformation is extremely small for normal loadings.

Deformation of Ceramics at Elevated Temperatures—If crystalline ceramics are loaded at elevated temperatures, marked inelastic deformation also may be produced. As an example, Wygant[1] subjected specimens of several pure oxide ceramics to torsional loading at elevated temperatures; the stress-strain

The authors are Professors in the Department of Engineering.
The advice of R. D. Johnston of the University of California and of R. D. Chipman of the Atomic International Division of North American Aviation, Inc., is acknowledged by the authors with much appreciation.

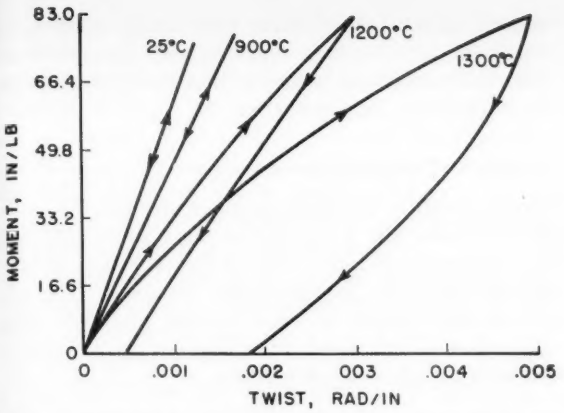


FIG. 1. Stress-strain characteristics for a hydrostatically pressed magnesia ceramic (after Wygant).

relations for hydrostatically pressed magnesia (MgO) are shown in Fig. 1. Marked hysteresis loops for samples above 900°C. may be seen, and the definite plasticity of crystalline MgO at elevated temperatures is clearly indicated. A similar behavior also is shown by sintered alumina ceramics, and it is apparent that this is a common characteristic of most crystalline oxides. It can be concluded, therefore, that ceramics are not truly brittle at elevated temperatures.

When crystalline ceramics are subjected to constant loadings at elevated temperatures for extended time periods, definite creep may develop. Wygant[1] also made some creep measurements with sintered oxide ceramics at several temperatures, and, for example, Fig. 2 shows the results for hydrostatically pressed magnesia under several stress levels at 1,300°C. It was noted by Wygant that a constant secondary creep rate is reached at constant stress when stress is not excessive. The length of time necessary for the creep rate to become constant diminished with increasing load and with increasing temperature.

The deformation characteristics of glasses, or ceramics containing a glassy phase, at elevated temperatures have been studied in some detail. As may be expected, the deformation at high temperatures because of the viscous flow of the glassy phase is considerable and follows essentially the flow behavior of liquids. A thorough discussion of the deformation of glasses at elevated temperatures is presented by Morey.[2] An analysis of the deformation characteristics of ceramics containing glassy phases has been made by Norton.[3]

In summary, therefore, the reduction in brittleness of ceramics at elevated temperatures is quite evident because of the existence of plasticity in crystalline ceramics and the viscous flow of glasses.

(2) *Strength Characteristics of Ceramics*

It is of interest to consider the following properties of ceramics at room temperature.

Strength Under Static Loading—Certainly the most significant characteristic here is the ability of most ceramics to support much larger loads in compression than in tension; in general, the compressive strengths of most ceramics are seven to ten times greater than their respective tensile strengths. In Table I are found some examples of strength values for several typical ceramics; it may be noted that tensile strengths range from values of a few hundred psi to about 40,000 psi, and that the compressive strengths of the respective materials are seven to ten times greater (with the exception of graphite, whose compressive strength-tensile strength ratio is lower). It seems to be a common observation that the failure of ceramics under static mechanical loadings is almost always of a tensile type. It appears that the vulnerability of ceramics to failure in static loading is associated with the development of tensile stress, whereas the capacity to carry load in shear and compression is much higher.

Strength Under Dynamic Loading—Ceramics are well known for their sensitivity to dynamic mechanical loads since the lack of plasticity at room temperature renders them susceptible to failure by impact loads (particularly if such loads produce localized stresses of magnitudes greater than the elastic limit; failures resulting from such dynamic loadings also are typically tensile in nature).

Some interest has been expressed recently in the behavior of ceramics on the application of cyclic loading, and, in particular, an effort has been made to determine whether fatigue failure occurs at room temperature. The failure of aluminum oxide specimens at room temperature under cyclic loading was studied by Williams;[4] it was found that the fatigue survival stress was approximately 0.57 of the single stroke bend strength. The fatigue survival strength of sintered alumina at temperatures up to 900°C.

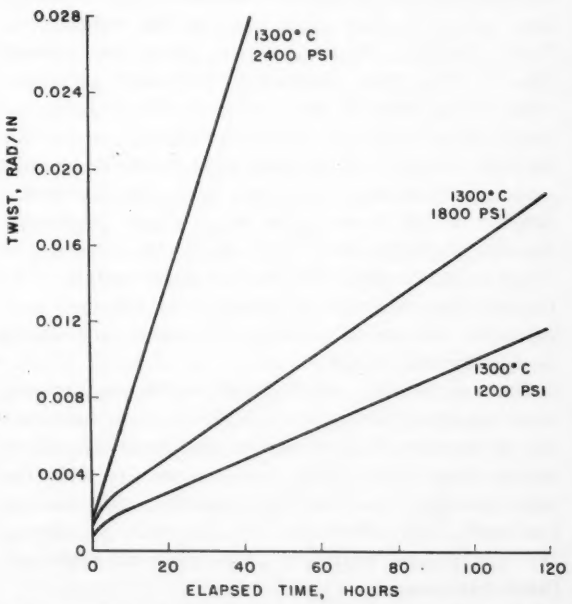


FIG. 2. Creep of hydrostatically pressed magnesia in torsion (after Wygant).

Table I
Approximate Property Values* for Some Ceramics at Room Temperature

Material	(1) Young's Modulus of Elasticity (psi)	(2) Tensile Strength (psi)	(3) Compressive Strength (psi)	(4) Bulk Specific Gravity
Alumina (Sintered Al_2O_3)	54×10^6	38,000	425,000	3.96
Beryllia (BeO)	46×10^6	13,800	110,000	3.06
Brick, Building (Porous)	$1.5\text{-}4.0 \times 10^5$	250 - 1500	2000 - 12,000	1.9 - 2.6
Forsterite (Mg_2SiO_4)	12×10^6	10,000	85,000	2.8
Graphite (c)	2.8×10^5	10,000	43,500	2.52
Mullite Porcelain	15×10^6	13,000	100,000	2.5
Steatite Porcelain	14×10^6	10,000	100,000	2.6
Sewer Pipe, Hollow Building Block (Vitrified Clay)	$4\text{-}6 \times 10^6$	800 - 2000	8,000 - 15,000	2.2 - 2.6
Zircon Porcelain	25×10^6	15,000	120,000	3.7

* From a Sampling of Property Values Reported in the Literature.

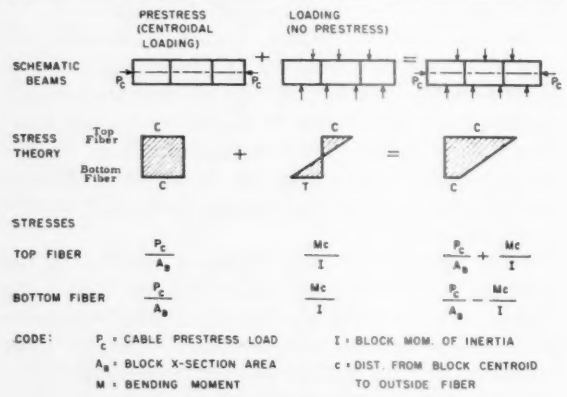


FIG. 3. Prestressing principles.

was found to be not significantly different from the room temperature figure.

The behavior of a whiteware ceramic under cyclic loading also was examined by Mizushima and Knapp.[5] Testing at room temperature indicated that its fatigue survival stress was about 0.80 of the single-stroke bend strength. It is apparent, from the research done to date, that ceramics do not suffer so great a reduction in strength due to cyclic loading as do typical metal alloys (such as steels, aluminum alloys, and others). In fact, the mechanism of failure of ceramics under cyclic loading needs more study; it may be that fatigue in the usual sense—i.e., where progressive damage develops—does not occur to the same degree in ceramics at room temperature as in metals. The fatigue characteristics of ceramics at elevated temperatures also are of considerable interest and should be investigated further.

Dynamic loading attributable to thermal stresses is an important factor to be considered in the successful use of ceramics in structures where rapid changes of temperature occur. This topic is one involving detailed analysis, and further discussion will not be presented here. Reference can be made to several excellent papers[6] pertinent to ceramic materials and thermal stresses.

In reviewing the several causes of mechanical failure of ceramic structural elements, it seems reasonable to conclude that the majority of failures are tensile in type, with a much smaller proportion of failures in shear (for example, failures resulting from certain types of thermal stresses).

(3) *Density Characteristics of Ceramics*

The densities of most common ceramic materials are relatively low, compared in magnitude with that of aluminum metal. Table I gives some specific gravity values for several typical ceramics. The relatively low density of most ceramic materials is a characteristic enhancing their promise as a primary material for lightweight structures.

Application of the Technique of Prestressing

The preceding review of physical properties of ceramics has emphasized an outstanding limitation of ceramics for structural uses—namely, their inability to support large tensile loads. This characteristic is undoubtedly related to the lack of ductility or plasticity of ceramics at room temperature.

Therefore, it seems clear that the successful use of ceramics for structures can be greatly increased by assuring that ceramic members are not subjected to tensile loadings. The application of prestressing techniques (which is being so successfully applied with concrete structures) may extend the use of ceramics for structural applications to a considerable degree. The simple principles of prestressing, as applied to a beam, are shown in Fig. 3; this may involve the use of wires or cables, loaded in tension, which produce a compressive stress in the ceramic material.

A preliminary study of the structural characteristics of prestressed ceramics has been made by Johnston, Chipman, and Knapp,[7] using hollow, glazed-building blocks. Cantilevered ceramic beams, when prestressed, were able to support static loads about six times greater than those expected without prestressing. A roughly corresponding increase in resistance to failure by impact loading was also shown with the application of prestressing.

The effects of prestressing a ceramic material on its resistance to failure by thermal shock were investigated by Wenger and Knapp;[8] marked improvement in resistance to failure by thermal shock was reported for prestressed specimens.

Recently some interest has been directed to the possibility of using prestressed ceramics as structural elements in high-speed aircraft and missiles. Such an application would take advantage of the high compressive strength and relatively low density of certain ceramics and might be useful where aerodynamic heating produces high-temperature environments. A preliminary study of the structural characteristics of prestressed ceramic wing-models has been made by Shanley, Knapp, and Needham.[9]

A promising future seems to exist for the use of prestressed ceramics in civil structures—for example, Shanley and others[7] have suggested the possibilities

in building construction, road paving, aircraft runways, bridges, and others where the compressive strength, abrasion resistance, and heat-resistant properties of ceramics can be utilized to advantage. A few examples of preliminary developments in the United States can be given: a prestressed ceramic slab has been constructed and tested[7] (Fig. 4), and a prestressed ceramic industrial shed was erected near Seattle, Wash., by Harry R. Powell in 1954.

One problem that deserves more attention is the true nature of the compressive failure of brittle materials. In applying the compressive load to the prestressed ceramic wing specimens referred to above,[9] it was found that the ceramic elements split longitudinally at low compressive stresses. This phenomenon prevented the full utilization of the compressive strength, as determined from small specimens. Although it seemed evident that the cracks were caused by transverse tensile stresses, it was difficult to account for this.

Nadai[10] shows photographs of a porcelain cylinder that had developed numerous "longitudinal cleavage cracks" under axial compression. The explanation given by Nadai follows the generally accepted idea that transverse tensile stresses are caused by a "wedging" action at the ends of the specimens. This explanation does not seem to apply to the ceramic wing elements because longitudinal cracking occurred in regions far removed from the end plates.

Shanley[9] has proposed a theory based on the atomic arrangement at the free surfaces. According to this theory, a large fraction of the atoms in the surface area are, in effect, forced outward by the axial compressive force as it is transmitted along the lines of action between atoms, as indicated in Fig. 5. This outward thrust must be balanced by transverse tensile stresses, which must go all the way through the specimen in order to be balanced by similar outward thrusts of atoms on the opposite surface.

This theory would explain why small cubical test specimens develop much higher compressive strengths than longer specimens made from the same material. Friction between the loaded surfaces and the testing machine head would supply resistance to transverse strains, thereby reducing the transverse tensile stresses. This action is exactly opposite to that of the "wedge" theory.

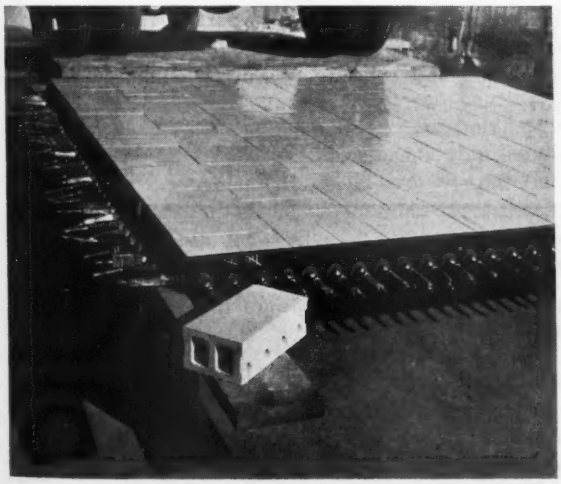
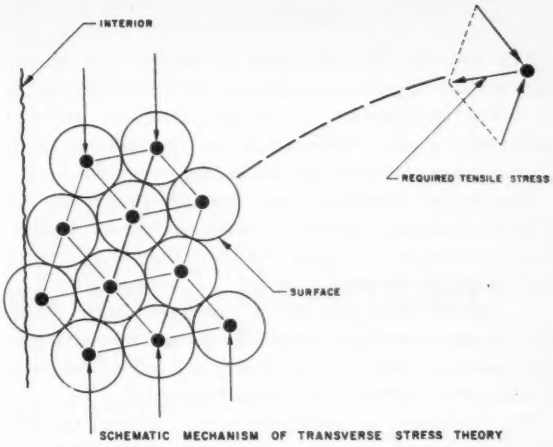


FIG. 4. "Two-way" prestressed ceramic slab.



SCHEMATIC MECHANISM OF TRANSVERSE STRESS THEORY

FIG. 5.

If such phenomena actually exist, it would seem advisable to provide a certain degree of transverse precompression or to use relatively small elements separated by gaskets which would provide some degree of transverse tensile strength.

Another interesting phenomenon observed in the ceramic wing study was the marked increase in compressive strength obtained when small longitudinal holes were present. In fact it was found that, up to a certain point, the compressive load carried by the specimen actually increased as material was removed.[9]

In parallel with the program on prestressing, the University of California, Los Angeles, has been investigating the possibility of making ceramic materials more ductile by providing "slip planes" of metal. Various ways of doing this have been tried, and preliminary results indicate that this may be a fruitful area for research.

Another interesting development is found in the recent work of Parker, Pask, Washburn, Gorum, and Luhman,[11] which has shown that cubic ceramic crystals possess substantial amounts of ductility at room temperature. Even the refractory ceramic material, magnesium oxide, elongated as much as 20 per cent on the tension side of a single crystal bend-test specimen. Purity and environmental effects play a role in brittleness, but the surface condition of the crystal seems to be a major factor in connection with ductility. The preparation of new surfaces by cleaving the crystal and the smoothness of the crystal surface produce highly increased ductility.

The preceding brief notes indicate that ceramics have large potentialities as structural materials, and that research along new lines should be encouraged.

Conclusions

The general characteristics of elastic and plastic deformation of ceramic materials have been reviewed; at room temperature crystalline ceramics undergo essentially elastic deformation only, while at high temperatures plasticity and creep may be evident.

The elastic constants and strength properties for various ceramics include a wide range of values. The compressive strength/density value is relatively high for certain ceramics.

It appears that failures of ceramics under static and dynamic loadings are chiefly tensile in character. This behavior seems to be closely related to the lack of plasticity of ceramics at room temperature.

The technique of prestressing may extend considerably the use of ceramics for structural applications. Prestressing ensures that the ceramic material is not subjected to tensile loads. Possibilities in the use of prestressed ceramics for structures of several types seem very promising.

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Dual Responsibility of IAS Membership *(Continued from page 33)*

growth: First, is it a balanced growth? Second, are we effectively encouraging new members to participate in Institute affairs? By balanced growth, I mean growth in all pertinent areas of the aero/space sciences. To achieve balanced growth, we must make it clear that we have a stimulating program and that we welcome the infusion of new talent and ideas.

The only real welcome is a personal welcome. If I as an individual have a colleague who would benefit from Institute membership and whose affiliation would advance the Institute and the aero/space sciences, I should extend my personal invitation and welcome to membership. Similarly, if a member is fully qualified for an advance in membership grade, the initiative should be taken by those who know of these qualifications. And, finally, those who have themselves been honored by election to Fellow grade should take seriously their responsibility in turn for nomination and selection of additional Fellow members.

If each member, whether Student, Associate, Member, Associate Fellow, or Fellow, will remember the clear objective of the Institute, so simply stated, "to advance the arts and sciences of aeronautics," and, being mindful of his dual responsibility to the past and the future and to his fellow members and future members, will encourage the advancement of the Institute through growth and participation of all its members, our future in the aero/space sciences individually and collectively will be enhanced materially.

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"In astronautics, the trajectory may depend much more strongly on the guidance concept than the guidance concept on the trajectory."

Some Problems of Space Navigation

Robert E. Roberson
Autonetics
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SPACE NAVIGATION is not a cut-and-dried discipline. It presents a large number of still unsolved problems, unmade decisions, and unanswered questions. One of the most basic problem areas relates to the requirements that have to be satisfied by space navigation systems. These are not yet known in detail, except perhaps for the very simplest astronautical missions.

Although there now is a large body of literature on space navigation, it is devoted almost exclusively to the design of suitable trajectories. And in choosing a trajectory, the most common criterion or viewpoint is propulsion efficiency. Relatively little has been said about how to guide the vehicle along its trajectory, once chosen—or, indeed, whether it *should* be guided along the nominal trajectory once deviations have occurred. (Some remarks on this question are given in reference 4.) The attention that *has* been given to the physical characteristics of space navigation systems[2,6,13] is generally concerned more with the methods by which position in space can be found and less with what to do with the information after it has been obtained.

To be sure, we have some idea about what constitutes a space navigation system. Experience, judgment, and intuition tell us that certain kinds of observations will have to be made, certain kinds of computations done, and certain kinds of instruments required. But intuition does not resolve all of the unanswered questions that underlie the complete preliminary design of a space navigation system. It takes a deliberate, systematic, and careful study.

Three facets of any such system may be distinguished: a guidance concept, or maneuver program; a mechanization scheme, or system block diagram; a physical design turned into hardware. The one thing basic to all is a set of guidance requirements. Establishing them should be the first step in any rational approach to the development of guidance systems for space flight. Indeed, this problem of requirements formulation should be regarded as the real foundation problem of space navigation. (These remarks are amplified in reference 11.)

In no sense do I belittle the many other problems of analysis and system mechanization that follow upon the requirements. These exist and are formidable. But this paper focuses just on some of the questions involved in the requirements study and leaves the other problem areas for future discussion. I would like to emphasize trajectory studies in relation to guidance, elaborate on the role of the basic guidance concept, and demonstrate the practical inseparability of some traditionally separate disciplines when they are applied in astronautics. Finally, in the hope of stimulating further investigations in this area, a possible program is suggested for attacking the requirements problems.

Logically, three kinds of requirements must be considered. The first of these are the *functional requirements*. What functions are to be performed by the guidance system? How are they related to the mission, and how do they vary through the trajectory phases? What is a complete set of guidance modes for the whole mission? The second kind of requirement is on *performance*. Having established the kind of job to be done, how *well* must it be done? Are there any critical performance parameters beyond the obvious ones of accuracy and reliability? How do the latter affect the operation? What kind of numerical specification should be attached to them? The third requirement area is one of *physical considerations*. What constraints are imposed on system

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mechanization by the astronautical environment? What test requirements are peculiar to guidance systems for astronautical missions?

No preliminary design investigation for space guidance can claim completeness without some attention to each of these three requirement areas. It is in these areas that the basic problems lie. To be sure, the requirement areas deserve different emphasis. The physical requirements are less important than the others in the initial stages of a preliminary design study. They grow in importance as thought is given to the physical devices needed to implement the mechanization scheme. But they cannot be neglected completely even at the beginning since they may reveal areas where early physical research is essential to forestall later delays in component development. For instance, even a cursory look at the physical requirements area demonstrates the need for research on such things as vacuum lubricants. However, in this paper the physical requirements area will be left aside in order to emphasize analytical and rational problems.

Functional Requirements

To look deeply into what is required of astronautical guidance systems, one must consider the mission and the means of accomplishing it. The functional requirements are mission oriented in the sense that quite different guidance modes are combined in an interplanetary instrument probe impacting on the destination planet and a manned expedition to the surface of that body. And, of course, the requirements for an interplanetary mission differ from those of lunar or interorbital ferry missions. But, in addition, requirements depend upon the propulsion used to accomplish the mission. The function of a system guiding a high-thrust, short-burning-time rocket—most of whose trajectory is free-flight—differs drastically from the analogous function for a low-thrust, continuous-burning (e.g., ion) rocket. There is relatively little carry-over from one of these cases to the other, and they must be treated separately from the outset.

Even after all of the basic cases of mission type, propulsion, and operational goals have been separated carefully, it is still not so simple as it might appear to establish the functional requirements on the guidance system. The reason for this is the especially close and unconventional interaction existing in astronautics among flight path (trajectory), guidance concept, and functional requirements. This point, frequently misunderstood, deserves special discussion and emphasis.

For missions entirely within the earth's atmosphere—e.g., a long-range cruise system for strategic bombardment—it is normal to think of the functional requirements on guidance as being established in the following way. A mission is prescribed in terms of its goals, propulsion, and vehicle form. The vehicle flight path is determined entirely by these factors. The guidance concept itself (how it should be steered and powered to get to the destination using position, velocity, and attitude signals obtained from the guidance system) is simple. Rather clearly it is best developed on the basis of aerodynamic, autopilot, and propulsion consideration. The functional requirements are established just by seeing what guidance operations have to be mechanized to carry out each flight path or trajectory phase. Typically, it is to supply the vehicle's position coordinates—and perhaps some attitude information. The function is relatively independent of flight path type and exact steering rule selected.

The picture begins to change with ballistic missiles. More of the flight is outside the atmosphere, and an analysis of free-flight trajectories is needed to determine guidance system cut-off coefficients or firing tables. The choice of flight path is still made mostly from considerations of operation, propulsion, and aerodynamics. But now an interaction between the trajectory chosen and the guidance concept starts to occur. For example, a guidance concept involving terminal guidance to minimize re-entry dispersion could utilize a shallower (propulsively more optimum) trajectory than one which terminates guidance at the end of main boost. The guidance concept becomes more complicated, and a more sophisticated treatment is required of the question, "What should the missile be doing now, given its instantaneous position and speed?" For the answer no longer is simply that it should return to its originally planned flight path. Instead, a new trajectory can be established which leads to a successful operation (a hit) just as well as the old one. Finally, the guidance functions themselves are more extensive, precise velocity information and cutoff signals being needed in addition to position and attitude.

Going to the case of earth satellites, the degree to which the guidance concept interacts with trajectory becomes much more pronounced. The orbital part of the trajectory (hence the whole operational value of the satellite) depends critically on the nature of the guidance at final rocket boost into orbit—whether it is open-cycle or closed-cycle guidance, and, if the latter, what information feedback is used. To be sure, the ascent trajectory is determined partly by aerodynamic and propulsion considerations—e.g., in the length of coast between main and final boost—but, even here, guidance considerations have begun to play an essential and inseparable role in the trajectory details.

In the case of lunar and interplanetary missions, this guidance-trajectory interaction grows to the point where guidance considerations can become of prime importance in the choice of trajectory, sharing this role only with propulsion. No longer may the trajectory be given beforehand and the guidance functions deduced from it. Now the guidance concept is sometimes chosen first—for example, to increase guidance reliability by system simplification. The resulting

trajectory then may be accepted as it comes out if the result does not clash too badly with other operational requirements. This might well be the case, for example, in interplanetary missions using low-thrust rockets.

The theses of these remarks can be summarized as follows:

(1) The trajectory cannot be analyzed purely on the basis of the mission without reference to guidance but must be considered *simultaneously* with the guidance concept. In astronautics, the trajectory may depend much more strongly on the guidance concept than the guidance concept on the trajectory.

(2) The functional requirements, which follow directly from the nature of the several trajectory phases, are irrevocably entwined with the guidance concept, the maneuver program. Because of this, it is grossly inconsistent to attempt to abstract the question, "What is the vehicle doing?" (in the sense of what kinematic quantities are to be supplied by the guidance system) from the question, "What *should* the vehicle be doing?" (in the sense of guidance concept).

For better or for worse, these mean that one must become reconciled to a gray area of interaction among traditionally independent disciplines—guidance, trajectory analysis, and (to a lesser extent) flight control.

Trajectory Analysis

The trajectory is given in terms of a specified initial position, velocity, and gravitational field, with or without the addition of steering program information. Regardless of how the trajectory is developed in combination with a guidance concept, the basic problems of trajectory analysis are to derive the correct position vs. time behavior of the vehicle and to deduce the trajectory changes that occur from variations in guidance, control, time sequencing, thrust level, corrective supplementary thrusts, and similar factors.

There are two general approaches to the problem. One is through numerical solution, numerical integration of the differential equations of motion. Large capacity high-speed digital computers ordinarily are used for this. The other method is analytical, and here there are several ways to proceed. It is well known that complete, explicit, analytic solutions for trajectory problems more sophisticated than the two-body problem cannot be obtained (except perhaps in rare isolated cases such as that discussed in reference 3.) But this does not prevent the application of analytical tools in the following ways.

First, one may seek essentially correct but partial answers. For example, one may see what properties of the trajectories can be deduced from Jacobi's integral of the motion, as in the excellent treatment by Buchheim[1] of lunar probe and satellite trajectories. The energy integral alone sometimes can give considerable insight into trajectory behavior, while the use of topological and phase plane methods offers attractive but generally unpursued possibilities.

A second kind of analytical approach simplifies the actual physical system by replacing it with a model that can be treated analytically. It usually takes the form of idealizing a situation as a two-body problem or as a series of two-body problems in which the influence of different perturbing bodies can be neglected successively. The author knows a number of persons using this approach on current problems, and it probably is quite general. However, I do not believe that this method has yet been adequately evaluated or its domain of applicability completely determined. It has the advantage of simplicity and leads to explicit solutions. On the other hand, the accuracy of the model may be relatively low, and the successive basic solutions somehow must be "pieced together."

A third analytical possibility sometimes is attractive—namely, the approximate solution of an exact problem by means of a perturbation or similar approximation method. This has been applied with notable success to some problems of earth satellites—for example, see references 8, 9, and 10—but does not seem to have been used on lunar or interplanetary trajectories in the same way, especially with guidance problems in mind. Yet such an approach may be of considerable value—for example, in analyzing trajectories of low-thrust rockets.

No general evaluation of these several methods of trajectory analysis can be made. Each has its own domain of special value. Computer studies are open to the usual objection that each solution is a special case and that it is difficult to get deep insight into the general trajectory properties using purely numerical methods. On the other hand, they seem the only way to get real accuracy in the results.

Computer studies can be (and often are) misused in two principal ways. One is that elaborate and voluminous numerical studies may be made of an oversimplified model, to an accuracy not justified by this model, with the resulting danger of getting lost in a mass of relatively useless data. The other is that the numerical solutions may be generated without taking full advantage of the long history of numerical procedures in astronomy. (To be sure, this often is caused by the failure of astronomers to update notation and methods that sometimes appear hopelessly archaic.)

The danger of oversimplification in making any abstract model is well known. In astronautical trajectory studies the point is clearly demostrated by comparing early two-dimensional lunar trajectory studies with later three-dimensional studies. Walters,[14] for example, has pointed out the problems of critical timing associated with the moon's orbital inclination, a three-dimensional aspect of the situation.

A recommended approach to trajectory analysis problems is to exploit the various analytical methods to the fullest extent possible, with careful attention to the possible qualitative effects of model oversimplification and analytical approximation. At this point the computer can play an extremely helpful role in

supplementing the analysis by filling in needed details, but the analytical rather than the numerical framework is the basic guide to the direction of the work. An outstanding example of the success of such an approach (to the problem of low-thrust interplanetary trajectories) is in connection with the work reported in reference 12.

Only after such possibilities have been exhausted should large-scale computer studies begin, then principally in the nature of verification and accuracy enhancement. Trajectory modifications can be accomplished thereafter by a relatively modest sequence of numerical trials. It appears that trajectory variations arising from guidance errors and similar effects then can be investigated quite nicely by a combination of perturbation and numerical methods. The author recognizes that computer studies are essential—and, in fact, that it may turn out that little analytical or quasi-analytical assistance will be forthcoming. But it is not clear that the latter has yet been attempted to the point where such a statement can be made.

Performance Requirements

The performance parameters which are significant in astronautics are not yet completely known. It is clear that they will be related to the measure used in defining mission effectiveness. Accuracy occurs to one at once as a major performance parameter; and so it is, in most applications. However, for other missions it may be less important than reliability and other factors.

Reliability itself plays a far more dominant role in astronautics than in terrestrial guidance systems (where it is certainly important enough!). Mission times are long, and possibilities of failure may be high without exceptional improvements over the reliability of today's equipment. Certainly reliability is a major performance parameter.

But accuracy and reliability are not the only factors. Weight is important, for example, especially for early systems where propulsion may be marginal for the desired payload. Thus, the first item of a performance requirement study is to find the performance parameters which actually are important to the operational success of the mission.

Complete performance specifications on the guidance system have to be established in the light of trade-offs which exist among the performance parameters and on the basis of the effect of these parameters on the chosen measure of mission effectiveness. Some unmade operational decisions will almost inevitably remain for most missions, preventing the complete establishment of specifications. In such cases, it is important to call out explicitly the areas of needed decisions. But even from the limited point of view of incomplete specifications, the same trade-off considerations can be extremely valuable in permitting *relative* evaluations of alternative guidance systems.

One element of the establishment of accuracy requirements is the determination of the effect of guidance errors on the trajectory. Work of this kind has been done[6, 7] but only for single trajectory phases—for example, a free-fall trajectory starting with prescribed initial conditions, but no subsequent trajectory correction phases. Similar studies are required where several trajectory phases are successively juxtaposed. And, as the next step, the operational effect of trajectory variations must be assessed.

A Suggested Program

Crystallizing the requirements on space vehicle guidance systems, thereby providing a rational foundation for the development of such systems, must attack the problems outlined above. With the hope that it will encourage additional investigation in this problem area, the author presumes to list a number of topics that he feels are worthy of attention. Together, these constitute an integrated program of basic space navigation investigations.

(1) *Literature Survey*

It should be noted, first of all, that up to the present there has been no comprehensive review of the existing literature on space navigation. This is a serious lack that should be remedied to point up areas that have not yet received adequate attention.

(2) *Mission Analysis*

The author feels strongly that the space navigation picture will remain murky until possible astronautical missions are better systematized. Mission classifications might include breakdown by origin, route, destination, functional purpose, payload nature and size, propulsion type, and similar factors. From the complete set of missions the trajectory implications can be investigated and a small set of basic trajectory requirements formulated. This greatly reduces the confusion of considering separately each of the many missions that can be conceived.

It can be anticipated that there will be two major distinct trajectory types feasible in the future. One of these is the intermittent thrust (main boost followed by discrete boosts or course corrections) as typified by present chemical fuel rockets. The other is the continuous or piecewise continuous thrust typified by the ion rocket. These initially will be low-thrust cases, but it should not be ruled out that future propulsion developments will result in the ability to maintain a high-level continuous thrust.

(3) *Mission Performance Criteria*

A basic question is the establishment of operational performance criteria. Clearly, it is unnecessary to ask for a certain degree of accuracy if much wider tolerances (even though they may result in grossly different trajectories) really have no significant operational effect on the conduct of the mission. And on the other hand, it is foolish to demand only a 1,000-

hour mean-time-to-failure if one of 600,000 hours really is needed.

(4) *Trajectory Analysis Methods*

Another surprising lack is a good integrated survey of trajectory analysis methods with astronautical rather than astronomical needs foremost. Here is a fine endeavor for someone! Among other things, any such survey should include attention to both analytical and numerical methods and should emphasize three questions: What are these methods?, What are their domains of applicability?, and How do they compare in effectiveness? At the same time, the desirability of simplification and improvement should be kept in mind.

(5) *Guidance Concept Development*

The effect of the guidance concept on trajectories is an area clearly needing attention. For intermittent thrust trajectories, the concept will enter primarily in the way course corrections are made—when or where, with what kind of steering program, and on the basis of what guidance information. Since the complete guidance concept can involve different guidance rationales during the several trajectory phases, each must be examined. Correction time and numbers of individual corrections should be varied to determine trade-offs between guidance accuracy and propulsion efficiency. And as a part of the guidance concept, special attention probably is warranted to the role of man in changing trajectories or performing a part of the guidance functions.

The guidance concept has a dominant position in relation to continuous thrust trajectories. Here the whole nature of the steering program interacts constantly with the trajectory. The problem is largely one of choosing steering programs simultaneously to get an operationally suitable trajectory and to promote the desired properties of the concept—completeness, explicitness, unambiguity, certainty, flexibility, and simplicity. (See reference 11.)

(6) *Guidance Computations*

In spite of past work on space navigation and guidance, little really is known about the details of the computations that must be done aboard the vehicle. Yet this may be vital in determining the complexity—and reliability—of the system. Deciding the computations needed is equivalent to considering the trajectory problem (in view of the chosen guidance concept) from the point of view of an on-board observer, relating the basic trajectory parameters to on-board observations. The goal, of course, should be maximum simplification of these computations consistent with accuracy and operational requirements.

(7) *Trajectory Variations*

After nominal trajectories are conceptually chosen, it is necessary to examine departures from them caused by such things as guidance errors and unpredicted thrust variations. Both the geometric and operational effects of these variations need to be considered, with special attention to the minimization of the effects of errors by particular choices of trajectory. For example, it has been shown[15] that for interplanetary trajectories certain choices of trajectory angle at the end of main boost can remove first-order effects of velocity errors at that point. Walters[14] has shown a similar effect with proper choice of initial velocity for lunar trajectories. Equally important is the need to consider the automatic correction of the effects of chance variations by careful and ingenious choice of guidance concept without compromising the simplicity of the mechanization.

As observed earlier in this paper, I believe that guidance considerations of this kind will be far more important in the choice of nominal trajectory for astronautical applications than has ever been the case heretofore.

In the case of low-thrust trajectories, variation considerations are as described above. But in this case, variations also must be constrained by the low-thrust levels likely to be available. In choosing a concept, special precautions must be taken to assure that no situation is permitted to arise from which recovery is impossible within the limits of available thrust.

Here is the list of problems. I hope that progress in the field of space navigation will soon make it obsolete!

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(*Continued on page 54*)

Hot gas servos are rapidly assuming an increasingly important position in power actuation systems for aircraft and missiles. Particularly with recent developments of positive displacement motors and high-performance servovalves for high-temperature applications, pneumatic systems are becoming competitive in weight, envelope, and performance when compared to hydraulic or electrical systems.

Pneumatic Motors for Aircraft Actuation Systems

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FIG. 2. Cam-piston air motor.

MUCH of the recent impetus for accelerated development in the field of pneumatics for power actuation has come about as a result of phenomenal advancements in manned aircraft and guided-missile technology. These advancements have resulted in new requirements for components and systems capable of exhibiting high levels of tolerance to adverse environments much more extreme than any hitherto encountered. These ever-increasing requirements, in particular, reflect extremely wide ranges of operating and ambient temperatures and the presence of atomic radiation.

As an energy source for power actuation and control, pneumatics presents a number of characteristics which are quite favorable in the light of these advancing operational requirements. Foremost among these is the fact that the fluid is thermally stable, and no changes in the physical state of the operating medium occur over extremely wide ranges of temperature. Also, the medium does not deteriorate when exposed to nuclear radiation and presents no handling, maintenance, or disposal problems which might otherwise result from fluid contamination.

In most airborne applications, a source of pneumatic fluid energy is readily available or can be conveniently supplied. On turbojet aircraft, compressor discharge air can be used directly or boosted to provide compressed air in relatively large quantities for continuous duty or intermittent power actuation. Auxiliary compressors or high-pressure bottled air or other gases can be conveniently carried to provide energy sources for limited duty applications. The products of combustion of rocket propellants from gas generators or from main propulsion engines may be used on rocket-powered missiles or aircraft as energy sources. These and other sources of high- and low-pressure pneumatic energy lend themselves to a variety of gas-powered servo types and applications.

The initial approach to the problem of high-temperature pneumatic actuation in aircraft received direction from the immediate problems presented by the requirements for actuation in the vicinity of the tailpipe of jet engines. Earliest applications include on-off and continuously modulated variable area tailpipe nozzle control and thrust reversal systems. Approaches to these problems are governed by ambient temperatures in the neighborhood of 700° to 1,000°F., with an available source of pneumatic energy existing in the form of compressor discharge air at pressures up to 270 psi and maximum temperatures in the neighborhood of 1,000°F. Normal system requirements cover power ranges from 10 to 100 h.p., depending upon the specific application. Engine envelope, weight limitations, and the necessity for unobstructed cooling of the tailpipe area present additional requirements concerning package size and weight.

Positive Displacement Motors

These composite requirements for performance, size, and weight lead to a more or less natural solution

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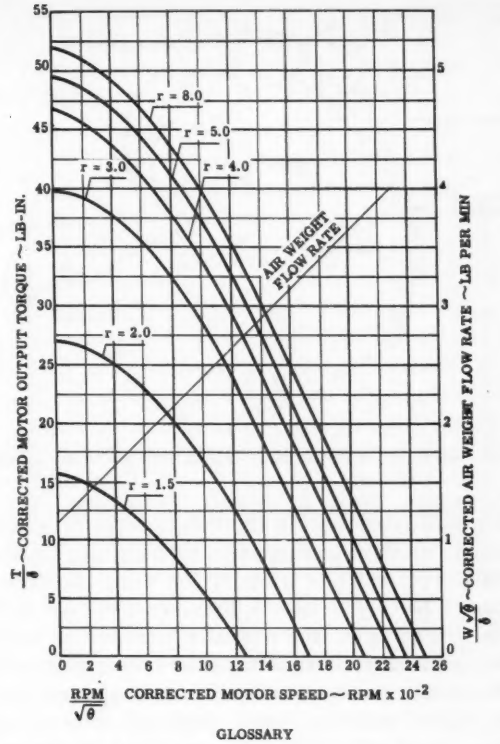
in the form of positive-displacement pneumatic motors utilizing a nonexpansion hot gas cycle. The use of the nonexpansion cycle assures maximum utilization of space and weight since it results in maximum torque per unit of displacement volume. In addition, the nonexpansion cycle provides high response and rapid reversal, and is ideally suited to modulating systems. Since the nonexpansion cycle uses none of the thermal energy in the gas, specific gas consumption is relatively high. However, within the range of most practical applications, this is not a serious problem since bleed-air flow requirements are generally well within the tolerance of turbojet engine compressors with a minimum of engine performance decay.

Positive displacement motors adapted to a partial expansion cycle are showing promise for many continuous duty applications, particularly where the fluid supply is limited, such as it might be in the case where the energy source is a hot gas generator using a liquid or solid propellant charge. With good leakage characteristics, motors of this type exhibit minimum specific propellant consumptions comparable to pneumatic turbine motors, and they have the additional advantage of being able to operate efficiently over a wider range of overall pressure ratio. Like the turbine, peak torque occurs at stall, but, unlike the turbine, the positive displacement motor exhibits the generally desirable characteristic of minimum rather than maximum gas flow at stall.

Performance

Current developments in the area of positive displacement rotary motors are represented by a number of types, prominent among them being the cam-piston, nutating disc, gear, and Lyssholm types. These various configurations cover a wide range of operational performance, and they vary in suitability for specific applications depending upon type and size. Both rotary and linear outputs are available through developments in high-temperature ball-screw jacks and other means of translating rotary to linear motion.

Typical steady-state performance characteristics of nonexpansion-cycle positive displacement motors are shown in Fig. 1. Torque is a maximum at stall and decays with motor speed. Horsepower peaks at some speed which is a function of the motor design. The decay in torque with speed is largely a problem in "breathing" efficiency and is a function of pressure drop in the inlet and exhaust ports and internal leakage. Since flow through the motor ports is, in effect, governed by the laws of gas flow through orifices, inlet and exhaust throttling losses are functions of weight flow; hence, losses are affected by motor speed (volumetric flow), gas temperature, and pressure ratio across the motor. Since the porting configuration does to a significant extent control motor runaway speed and speed for maximum horsepower, different configurations will exhibit varying suitability for specific applications. For example, the stacked cam-piston


r = 8.0
r = 5.0
r = 4.0
r = 3.0
r = 2.0
r = 1.5
AIR WEIGHT FLOW RATE
$\frac{T}{\delta}$ ~ CORRECTED MOTOR OUTPUT TORQUE ~ LB-IN.
$\frac{W\sqrt{\theta}}{\delta}$ ~ CORRECTED AIR WEIGHT FLOW RATE ~ LB PER MIN
$\frac{RPM}{\sqrt{\theta}}$ CORRECTED MOTOR SPEED ~ RPM x 10^{-2}

GLOSSARY

T: Motor Output Torque, lb in.

δ: $\frac{P_1}{P_0}$ (Dimensionless), where P_1 = Motor Inlet Absolute Pressure psia, and P_0 = Standard Sea Level Pressure, 14.7 psia

θ: $\frac{T_1}{T_0}$ (Dimensionless), where T_1 = Motor Inlet Absolute Temperature, deg. R, and T_0 = Standard Sea Level Temperature, 519R

r: Motor Pressure Ratio, $\frac{P_1}{P_d}$ (Dimensionless), where,

P_d = Motor Absolute Discharge Pressure, psia

W: Motor Air Weight Flow Rate, lb per min

FIG. 1. Performance characteristics of 2.44 in. piston diameter cam-piston motor.

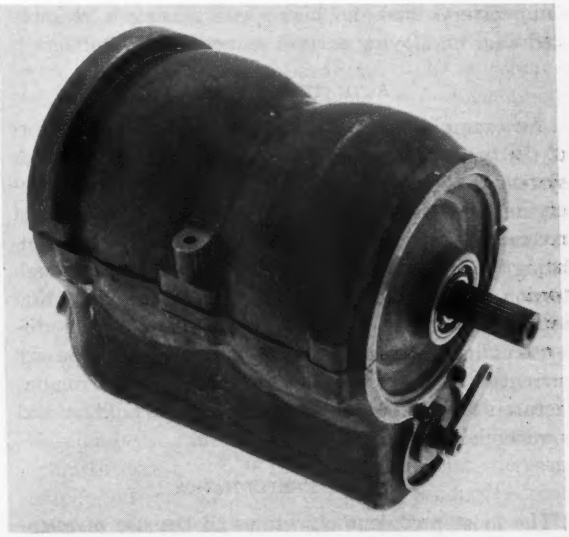


FIG. 3. Nutating disc air motor.

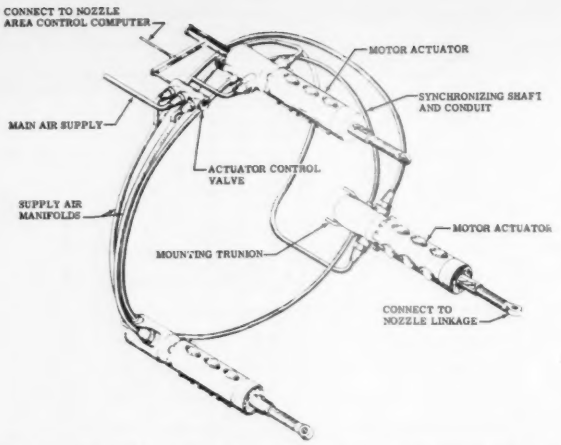


FIG. 4. Cam-piston motor variable area nozzle actuator system.

motor illustrated in Fig. 2, which provides a very favorable envelope configuration for many applications of this type, exhibits a speed for peak horsepower around 1,200 r.p.m. and a runaway speed of 2,000 r.p.m. In contrast, the nutating disc type of motor illustrated in Fig. 3 exhibits a peak horsepower speed in the neighborhood of 6,000 r.p.m. and a correspondingly higher runaway speed. Both of these motors achieve essentially the same combined mechanical and pressure efficiency at peak horsepower.

Other configurations, such as the gear and Lyssholm types, generally peak at speeds considerably higher than those cited above. Low-speed motors, such as the cam-piston type illustrated, are well suited to direct-drive linear output systems using ball-screw jacks, with envelopes compatible with locations in the area of the tailpipe annulus and output speeds being those generally required by nozzle area controls and thrust reversers. Higher speed configurations with gearing are suitable for similar applications with different envelope and mounting problems. Low-speed configurations are particularly well suited to extreme temperatures since no high-speed gearing is required and wear on moving parts is reduced to a minimum.

Actuation Systems

An example of a system utilizing pneumatic motors of the types discussed above is shown in Fig. 4. This system is typical of current developments in turbojet engine pneumatic variable area tailpipe and thrust reverser systems. The system is a closed-loop modulating type with synchronization being obtained through torsion cables which provide a mechanical connection between motors capable of absorbing moderate differences in motor output. Systems of this type are currently under test by engine and airframe manufacturers for installation in advanced-type military and commercial aircraft.

Dynamic Performance

The most prevalent objections to the use of pneumatics as a control medium in aircraft and missiles have been centered around the so-called "sponginess" inherent in the use of low-bulk modulus fluids. Unfavorable comparisons, for the most part based on the use of hydraulic fluids, tend to disappear at higher temperatures. While the bulk modulus of air, for instance, remains for all practica purposes unaffected by temperature, the bulk modulus of hydraulic oil decays rapidly, being only about one third of its low-temperature value at 500°F. Extrapolated to temperatures of 1,000°F., the bulk modulus of current hydraulic fluids is reduced to values quite comparable to air at equivalent pressure levels. Such an extrapolation is beyond the present state of the art with respect to high-temperature hydraulics. Programs concerned with the development of high-temperature hydraulic fluids are continuing, with considerable emphasis being placed on silicate and phosphate ester and other synthetic base fluids. Other approaches under investigation include the use of liquid metals, such as sodium, potassium, lithium, and cesium combinations. However, for the most part, applications of hydraulics at temperatures in excess of 500°F. have been accommodated only through the use of cooling methods to forestall thermal instability and breakdown of lubricating qualities of the fluid.

A similar situation exists with electrical power systems, with cooling required to prevent breakdown of insulation and magnetoelectrical qualities of core materials. The use of such operating "crutches," however, is reaching limits of applicability. The use of fuel as a heat sink, for example, is becoming severely limited because of the thermal instability barriers in the fuel itself. Rising ram air and skin temperatures further compound the problems of heat transfer, particularly since bulky heat exchangers and provisions for large ventilating areas around components are incompatible with the requirements for compact, low-drag configurations for high-speed flight.

Relatively favorable fluid characteristics, coupled with the use of the positive displacement motor in pneumatic servos, have resulted in stiffness and frequency-response characteristics that are suitable for almost any airborne power-actuation application requiring high response at elevated temperatures. The response of the motor to load changes is a function of the spring constant of the trapped fluid in the motor working chambers, which is related to load and the area-stroke relationship within the motor. As a comparative example, the motor with ball screw, in effect, strokes many times for a given actuation distance, and therefore the effective ratio of ram area to stroke is inherently many times greater than that of an equivalent piston actuator. Roughly, the relative stiffness of the motor plus ball screw and the piston actuator compare in accordance with N/k, where N is proportional to the number of effective motor strokes per actuation distance, and k is proportional to the efficiency of the ball screw. The value of k is always less than one; hence, the motor with ball screw is stiffer than the comparable piston

actuator by a factor which is of the order of the number of times the motor exhausts during each actuation distance. The natural frequencies of the motor and piston actuator will compare in accordance with the square root of this relationship. From this relationship, it can be seen that a motor—such as the cam-piston configuration illustrated in Fig. 2—which has three pistons, each stroking six times per revolution, combined with a ball screw having a lead of 0.25 in. per revolution, will exhibit a stiffness many times that of a piston actuator capable of driving the same load over a moderate stroke distance.

Fig. 5 illustrates some early experimental frequency response characteristics obtained with a loaded cam-piston motor operating on low-pressure air. The control loop around the motor was closed with a high-response electropneumatic servovalve. Although air temperature was low, the motor was operated dry without lubrication. Continuing programs to reduce motor inertia and to improve valve spool design are expected to improve substantially the performance shown. Response flat to frequencies in excess of 100 rad. per sec. with improved phase lag characteristics is expected to be achieved in the near future.

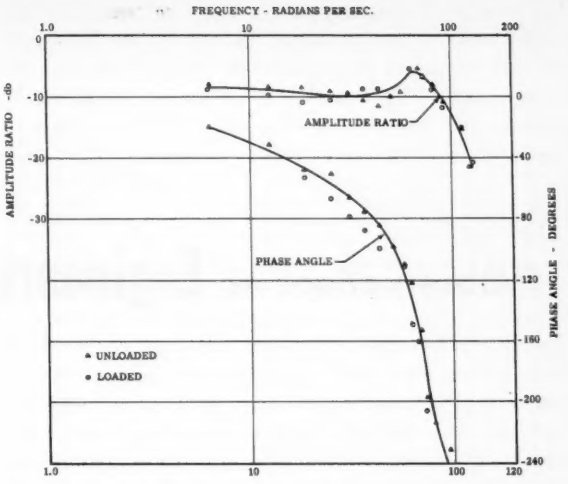


FIG. 5. Experimental closed-loop frequency response electro-pneumatic valve and cam-piston motor.

MATERIALS AND SEALS

Some of the most important aspects of the high-temperature pneumatic servo development effort have been and are currently concerned with high-temperature materials, seals, and lubricants.

The search for structural and bearing materials which provide high strength to weight ratio and retain resistance to corrosion, wear, and galling at high temperature has been an exhaustive one. This search not only has been concerned with material properties but also has been absorbed in the equally important problem of developing new methods and equipment for machining and fabricating many extremely hard and previously unworkable materials. Considerable success has been achieved with the use of high-strength stainless steels, Haynes Stellite, Titanium, Inconel X, GMR 235, and other superalloys for structural components, with wear-resistant tool steels, sintered carbides, and Haynes alloys providing satisfactory components for applications subject to heavy wear and bearing loads. In order to minimize friction and galling in the absence of lubrication, surface coatings, such as electroless nickel plating, aluminum oxide, and tungsten carbide flame plating, have been used successfully on certain combinations of base materials. Superfine finishes have been shown to greatly reduce wear and friction at high temperature. Some limited success has been achieved with dry film lubricants, and a number of current programs are under way to further evaluate the use of dry powdered lubricants for application in the area of 1,000°F. These programs concerned with the development of materials, surfaces, and lubricants have resulted in a continuing increase in operational life expectancy of high-temperature pneumatic servo components.

Sealing problems on airborne pneumatic equipment are generally not so serious as those on hydraulic equipment. Leakage of fluid does not present a fire hazard, and in most applications the fluid reservoir is essentially of unlimited capacity. No return lines are required, resulting in less complex and more reliable systems. The less stringent leakage requirements allow a wider use of metallic seals since, normally, dimensional tolerances must be held closer on metallic seals than on elastomeric seals. Metal reed seals are used successfully for dynamic shaft sealing, with metallic O-rings being used for static seals. Seals of carbon-graphite compounds and asbestos yarn, supported by inconel mesh screen, also indicate promise. Piston rings of Graphitar or Haynes Stellite 6B offer a minimum of friction and galling in piston ring seal applications at 1,000°F.

All of these programs continue to further support the trend toward pneumatics in hot gas power actuation systems for airborne applications. The success of programs of investigation and hardware development to date indicates that at high temperature pneumatics has the capability of performing practically any task currently assigned to electrical or hydraulic power actuation systems, including primary flight-control surface actuation on both manned aircraft and guided missiles. Experimental systems designed for operation in the area of 1,000°F.—including thrust reversers, jet-engine nozzle area controls, primary flight controls, and a number of others—are in various stages of evaluation at airframe and engine manufacturers. Current programs of development in materials and seals are aimed at increasing the range of temperatures to 1,500°F. and higher, with increasing emphasis being placed on the use of products of combustion of propellants for both high-response control applications and continuous duty accessory drives.

How "real" is our engineering shortage? An outline of the weaknesses and strengths of our undergraduate and graduate programs, and some suggested steps to be taken by Government and industry.

Observations on Engineering Education

Frederick Emmons Terman
Stanford University

THE LAUNCHING of Sputnik by the Russians greatly stimulated interest in education. Politicians and other headline seekers have enthusiastically joined in the discussion, with the result that there is often more confusion than understanding. Against this background an attempt will be made to provide some perspective with respect to several aspects of engineering education which are particularly timely today.

The So-Called Shortage of Engineers

In recent years much has been heard about the shortage of engineers and scientists. However, the statistics compiled by the U.S. Office of Education show that in each of the last several years just over 25 per cent of the men receiving Bachelor's degrees from our colleges did so as a result of the successful completion of a course in engineering or science. This is probably about as high a proportion of our young men as should go into engineering or science.

Researches into the supply and demand for engineers, moreover, do not substantiate the view that there is really a shortage of men with training in engineering and science to do work which requires such training.* For example:

(1) Engineers recruited for positions which can be filled only by men with engineering training do not receive higher pay than engineers who are recruited for quasi-engineering positions, such as sales and administration, which could if necessary be filled by non-engineers.

(2) Statistics show that, although engineers and scientists going into industry directly from college with a B.S. degree receive initially higher wages than their nonengineering classmates, the income of those entering such fields as sales, accounting, and general business rises more rapidly than the income of engineers, and in 10 years is on the average greater than that of the average engineer 10 years beyond his Bachelor's degree. If there really were a shortage of engineers, then, after an engineer had been out of college 5 or 10 years and had enough seasoning to know his way around, his financial advantage relative to other groups of college graduates should increase rather than disappear.

It might be argued that there must be a shortage of engineers because of the frenzied recruiting of college graduates that goes on. However, the salary received by the typical engineer in his first year out of college does not differ significantly from the wages paid a good journeyman machinist or a really good radio technician who is the same number of years out of high school. Thus, the apparent shortage of engineers coming out of college is in part a result of the fact that, when a corporation is given the opportunity to employ a college-trained engineer at the same wage rate as a skilled technician, the man with the college training is preferred, although in many cases he is given technician work to do.

Need for Higher Undergraduate Standards

The real need in engineering today is not for more warm bodies stamped with the letters B.S. but, rather, for engineers of better quality. The decade immediately ahead, in which there will be great pressure of numbers on the colleges, presents an ideal opportunity to raise standards for admission.

It is not generally appreciated how low admissions are in many schools in this country today. At 24 of the 47 state universities† in this country, any state resident

* See, for example, David Blank and George Stigler, *The Demand and Supply of Scientific Personnel*; National Bureau of Economic Research, Inc., New York, 1957.

Condensed by the author from his luncheon address on "Future Trends in Engineering Education," presented at the IAS National Summer Meeting, Los Angeles, Calif., July 8–11, 1958.

The author is Provost and formerly Dean of Engineering.

† The term "state" university as here used means the senior tax-supported school in the state. Many states have additional tax-supported institutions of higher education; in general, these have standards lower than those of the state university.

who holds a diploma from an accredited high school is entitled to enter the state university. In the remaining 23 states, a higher standard is maintained. For example, at one of these 23 institutions an entering freshman must have a recommendation from his high school, as well as its diploma! Another one of these 23 state universities with higher than minimum standards requires that at least three of the high school units be in academic subjects. These requirements are to be considered in the context of laws that typically require that a youngster stay in school until he either is 18 or has graduated from high school, and of the common practice for our public schools to provide a guaranteed annual pass. Under these circumstances, a high school diploma means merely that the recipient has served a 4-year sentence without serious truancy.

It would not seem unreasonable to require that a student entering any college possess qualifications that are at least a modicum higher than those represented by mere high school graduation under these conditions. By raising standards, teachers and space could be conserved for the benefit of those students who stood to benefit from their college experience. Also, if classes were purged of the dullards, they could be conducted at a higher level, with the result that properly qualified students would obtain a better college education. Finally, but not least, much of the taxpayers' money would be saved.

Graduate Work

Another way to improve the quality of our engineers is through the training after graduation of those who have done well in their undergraduate studies. Before World War II few engineers went on for graduate work, and industry gave only a minimum of recognition to such training as far as assignment or initial salary was concerned.

Since World War II this situation has changed greatly. Industry now eagerly seeks men with advanced training and is willing to pay a substantial premium for them, especially if they possess a Ph.D. degree. In addition, able young men interested in the new exciting fields of jets, transistors, computers, nuclear power, space technology, etc., need more and better intellectual tools than can be acquired in a 4-year program of study in order to master the complicated technical problems involved in these fields. As a result, approximately one engineer in five now goes on to a Master's degree and one in 50 completes work for a doctorate, according to U.S. Office of Education statistics. Many others do some graduate work, but not enough for a degree.

Nearly all graduate students in engineering or science require financial assistance at least on a subsistence level. Research assistantships on government projects are the most important single source of financial aid for graduate students. These part-time jobs not only finance graduate study but at the same time provide valuable training in research. Fellowships supported on an annual basis by corporations have since World War II also become an important factor in graduate education. Such fellowships are particularly satisfactory for getting men started in graduate work because they enable the recipient to devote full time to his studies.

Another important means of financing graduate students to further education is through work-study programs, in which the engineer works either full time or part time while carrying on part-time graduate work. The traditional form of work-study programs has consisted of full-time work during the day and one course a term during the evening. This arrangement has the disadvantage, however, of requiring 4 or 5 years for a man to complete the same graduate training that he could complete in 9 months of full-time study or in 2 school years as a half-time assistant. This disadvantage is overcome in new educational patterns in which the man works somewhat less than full time in industry while going to school from one-third to one-half time, and can receive a Master's degree in as little as 2 years while still earning a substantial, and sometimes actually full-time, salary.

A Larger Graduate Program in Engineering Is Needed

At the present time the demand for engineers with graduate training is far greater than the supply—a situation that means companies are being forced to get along with less competent men than they really need. In particular, at the Ph.D. level, the supply is hopelessly inadequate in relation to the demand.

In view of this, it is natural to ask whether it is practical to increase substantially the number of engineering students who go on for graduate work. It has already been pointed out that one engineer in five obtains a Master's degree and one in about 50 a Doctor's degree. It should be possible to increase these proportions greatly. Probably at least two in five of those who graduate in engineering would profit from a year of organized graduate study, and at least 10 per cent—and preferably 20 per cent—should ultimately obtain a Doctor's degree. These proportions may seem high, but they are not unreasonable when one notes that in both chemistry and physics about 20 per cent of those receiving Bachelor's degrees complete work for a doctorate.

A major expansion of graduate programs in engineering requires that several things take place:

(1) The Government must enlarge very considerably its support of research in our engineering colleges.

(2) Industry must play an even stronger supporting role by expanding its fellowship support, developing further its work-study programs, and also aiding in special ways individual institutions in which it has a particular interest. Industry can also help educate the engineering profession at large to the fact that it is

(*Continued on page 54*)

Eventually the airlines will derive their major income
from mail, express, and freight transportation.
The short-field aircraft will then be of particular importance.

Commercial Air Cargo Potential

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Fairchild Engine and Airplane Corporation

THE PURPOSE of this discussion is to anticipate the minimum range penetration of the cargo market by short-field aircraft. The trends in markets, common carriers, and design that will affect short-range transportation of air cargo will be analyzed. Only distances up to 500 miles will be investigated.

It is assumed that the short-range carriers feed the transcontinental and intercontinental markets. Since the short-field airplane is not now in use by any common carrier, its initial use may have to be supported by some form of underwriting. One possibility would be the carrying of first- through fourth-class mail. Present common carriers have gone through similar periods of help as new equipment was introduced into their system or when their operation was just beginning to grow to economic independence. For example, Fig. 1 shows the support given to United Air Lines, Inc., during its early years of growth by mail operating revenues. Similar plots could be shown for other airlines. Similar benefits have been given in the past to the ground operating common carriers. Certainly everyone recalls right-of-way grants to the railroad, mail pay, highway maintenance, etc. It has always been the policy of governmental regulating agencies to promote market growth and equipment improvement.

Interrelation of Market Location

In order to determine eventually the size of the short-field aircraft market, it is first necessary to know the location of major traffic centers. Certain major cities in the United States are responsible for generating and terminating most of the air freight now being carried. Fig. 2, based on reference 3, shows the geographic relationship of these cities. Each metropolitan area shown is responsible for over 1 per cent of the total air cargo tonnage transported in the United States. These 22 cities are currently accounting for over 81 per cent of the total enplaned cargo. The ten major cities are, in order: New York, Chicago, Los Angeles, Detroit, San Francisco, Cleveland, Boston, Philadelphia, Dallas, and Washington, D.C.

The ten most important markets for truck unloading of agricultural products are,[5] in order: Los Angeles, New York, Philadelphia, Atlanta, Boston, Chicago, San Francisco, St. Louis, Washington, D.C., and New Orleans. Seven cities are common to both lists.

Fig. 3 indicates the interrelation of these cities when a radius of 250 miles is scribed around each city. For all intent, over one half of the United States can feed

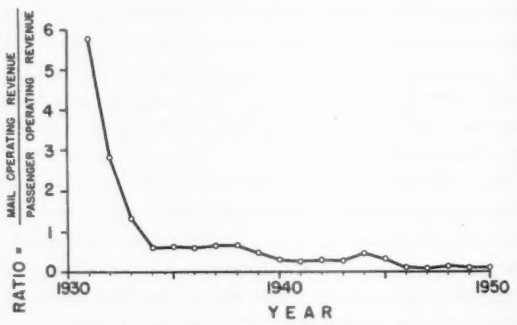

FIG. 1. Operating revenue ratio.[8]

FIG. 2. Metropolitan centers from which 1 per cent of total U.S. air cargo tonnage is generated.

Mr. Arata is Chief Project Engineer—Aircraft, Fairchild Aircraft Division.

air cargo into and out from the major cities. From a time standpoint, each 250-mile arc is equivalent to 1 hour by short-field aircraft or about 8 hours by truck.

Fig. 4 shows the complete support from almost the entire United States when arcs of 500 miles are struck from the cities listed in Fig. 2. Each arc represents a 2-hour flight by short-field aircraft or 16 hours by truck. It is agreed that ground traffic can alter truck time.

Airports

Accepting a possible penetration by the short-field aircraft into the current common carriers, we must first look briefly at the airport situation. Perhaps a better term would be "airstop" for the short-field airplane. That is—turnaround time and daily utilization are important.

In order to keep airstop acreage to a minimum, every effort should be made to utilize a single runway system. A similar recommendation was previously made by the President's Airport Commission.[6]

The same reference mentioned that, for 87 typical metropolitan centers in the United States, the average distance from the airport to the city center is 7 miles. In most cases, these cities have Class 6 airports or better.

The breakdown of airport classes is given in Fig. 5. Note the relationship between paved and unpaved runways. While a large percentage of the smaller airports are in small communities where air cargo will be marginal for some time to come, it can be speculated that close-in space for 500-ft. runways will not be a major problem in any city.

Fig. 6 is another way of putting the problem of airstop location relative to the city center. It can be concluded that the small airport is the only economical way of securing a close-in airport.

Perhaps our approach should be: *Bring the cargo transports to the trucks and railways, not trucks to the airports.* First, each major city has at least one railway freight classifying yard. These yards are usually located within 3 miles of the city center. Thus, by utilizing a portion of the yard space, a 100 ft. by 500 ft. airstop can be constructed. The benefits are:

(1) The aircraft are brought closer to the city center.
(2) Existing ground space is used.
(3) Handling time between aircraft and rail cars is minimized.

In addition to the short strip, a classifying dock should be constructed. This approach should minimize carload and LCL classifying. That is, instead of switching freight cars all over, to and from neighboring factories, some of the loading can be done at the classifying yard before a train is formed.

The same approach can be made by using existing highway freight terminals. Freight terminals are usually located close-in and are smaller in size than rail yards. This complicates the desire to bring in a short-field airplane. By using a portion of the parking area, an airstop can be constructed. Since consolidating docks are usually already in existence, the costs should be less than those for adapting a rail yard to

FIG. 3. Interrelation of metropolitan centers—radius = 250 miles.

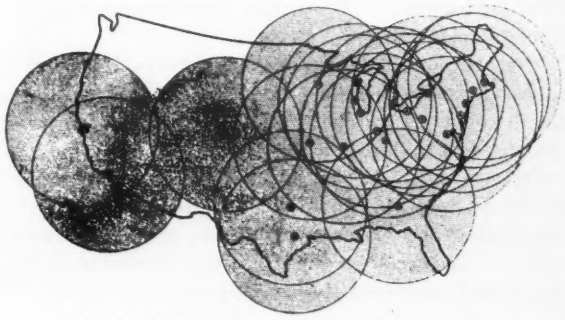

FIG. 4. Interrelation of metropolitan centers—radius = 500 miles.

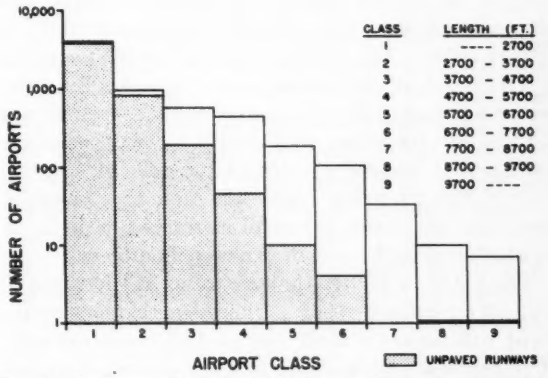

FIG. 5. Summary of existing U.S. airports (December 31, 1950).

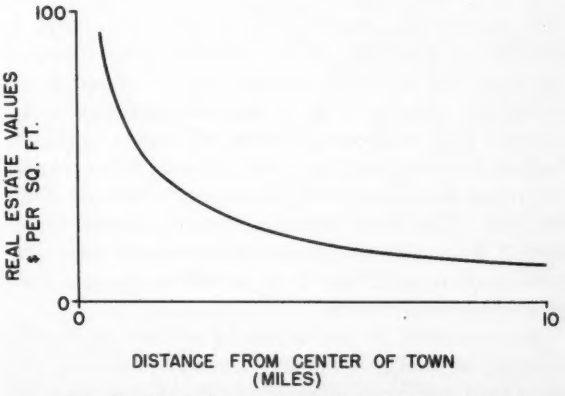

FIG. 6. General cost trend of property values.

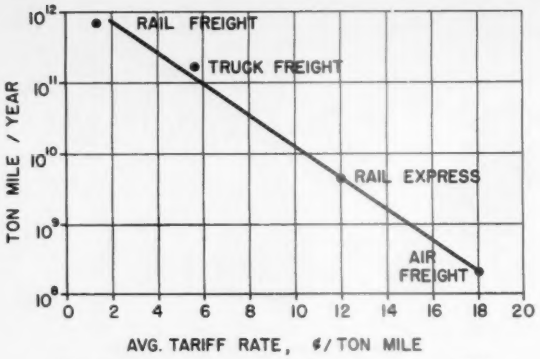

FIG. 7. Domestic freight volume vs. rates, 1954.

short-field aircraft. This arrangement should decrease transit time for cargo.

If geographic or technical conditions prohibit utilization of existing railway or highway freight yards, then an airstop must be constructed in a park area, in a clearing of existing buildings, or by strengthening a warehouse roof. In any case, the following factors should be considered in airstop site selection: reasonable initial cost, reasonable tax rate, adequate airway approach, adequate highway access, desired railway access, and space for a cargo classifying area.

Interrelation of Volume and Tariff

Fig. 7 illustrates the close relationship between cargo volume and tariff rates. Air freight volume has changed little since 1951 when the airlines carried 2.4×10^8 ton-miles. The 1954 figure was 2.6×10^8 ton-miles.

Truck freight also showed some increase. In 1951, with an average rate of 5.2 cents/ton-mile, they carried 1.82×10^{11} ton-miles; while in 1954, even though the average rate changed to 5.7 cents/ton-mile, they carried 2.08×10^{11} ton-miles. Since the same type of equipment has been used, the small increases can probably be attributed to the growth in national business.

The CAA[4] estimates that air cargo will increase to 8×10^8 ton-miles by 1965. This infers that new equipment will permit a tariff rate of 15.5 cents/ton-mile. It is believed that by 1965 new equipment, including short-field aircraft, should permit an even higher rate of cargo carrying.

It is further believed that the short-range aircraft will provide the greatest gain because most cargo is carried less than 500 miles. Only by close attention to design will short-field aircraft permit reduced direct operating costs, as well as indirect operating costs. In most plots of direct operating cost versus range, the high costs are usually the extremely short distances and at greater distances when it is necessary to trade cargo for fuel. Therefore, when a short-field aircraft is designed, it must be specifically tailored for its own optimum range in order that it will be able to compete with ground common carriers.

As mentioned in the beginning of this paper, the carrying of mail is a worthy means of promoting the short-field airplane. During the fiscal year of 1952 only 6 per cent by weight of mail went first class, while 60 per cent moved fourth class. Thus, it appears that carriers considering short-field airplanes should more closely study the quantities and movements of U.S. mail.

While the cargo market has been increasing each year, it is of more interest to compare its growth with passenger revenues. Fig. 8 compares the per cent of revenue from cargo over a given time span for both airlines and railroads. Assuming the availability of proper equipment, the trend seems to be that eventually the airlines also will derive their major income from carrying mail, express, and freight. Fig. 8 implies that by 1965 the airlines could derive 40 per cent of their income from cargo hauling.

Design Considerations

The prime advantage that short-field aircraft have over ground carriers is speed. Ground transportation speeds have not changed appreciably in the last 20 years. Airspeeds, besides increasing year by year, are many times faster. Thus, for the future, the speed differential between ground and air travel will increase more each year. Fig. 9 is a cruising speed chart for different carriers. Six carriers are shown. Freight train speed is shown as 30 m.p.h. This is somewhat optimistic since the average running speed reported by the railroads in 1951 was 18.2 m.p.h. In 1921 the running speed was 11.3 m.p.h. Highway trucks, regardless of power available, are limited by speed regulations and traffic congestion. In any event, local stops

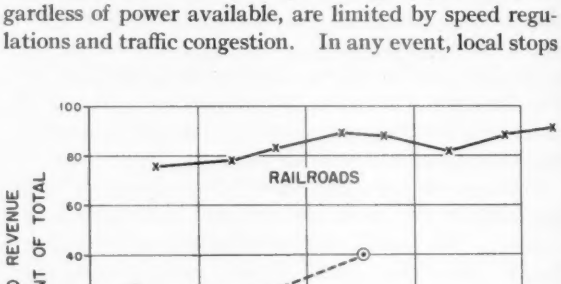

FIG. 8. Cargo revenue trends.

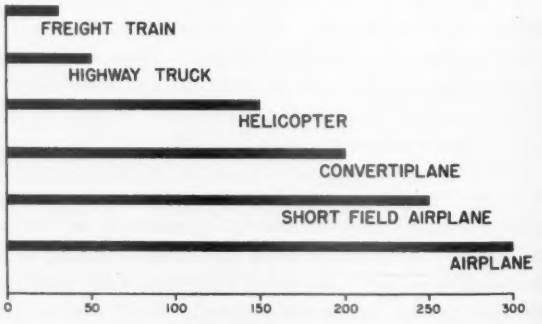

FIG. 9. Cruise speed chart—short-range intercity cargo carriers.

coupled with the inherent environment for the ground vehicles will probably permit little change in cruise speed in the next 10 years.

Helicopters and convertiplanes are included in Fig. 9 only as a matter of reference. It is believed that large cargo helicopters and convertiplanes will not be in general commercial cargo use during the next 10 years.

It is accepted that cargo airplanes utilizing regular airports will have a cruise speed of 300 m.p.h. or better. However, because of the "tricks" necessary to achieve the short-field airplane, its speed should be somewhat less. The following five factors are important considerations in developing a satisfactory small-field airplane: power plant, pressurization, fuselage configuration, cargo handling techniques, and landing gear.

Power Plant

It is believed that turboprop power plants will be used. Whether the free-turbine will be the best result will depend upon the engine manufacturers.

Pressurization

Even though the short-field airplane will be limited primarily to short distances, it is believed that the flight station should be pressurized in order that the crew can fly the airplane at altitudes compatible with best turboprop operating conditions. Even on distances as short as 200 miles economies can result. With improved electronic navigation and traffic control aids, the day may come when cargo aircraft can operate without a flight crew.

Fuselage Configuration

For optimum space utilization, the cargo compartment should have a rectangular cross-section. Full rear-end loading with an integral adjustable ramp will also be incorporated.

Cargo Handling Techniques

It is believed that the conventional cargo floor will be replaced by an integral pallet system. A previous paper[1] outlined a proposed arrangement. For optimum turnaround time, cargo preloading will be necessary.

Landing Gear

As noted in Fig. 5, the majority of the small airports in the United States are unpaved; therefore, provisions should be made for a high flotation landing gear. Of course, for most scheduled operations, paved areas will probably be available. Well-proved features such as antiskid braking devices will be incorporated.

Common Carrier Penetration

The ability of cargo air transports to compete with the ground common carriers in the next few years is, of course, subject to estimation. Fig. 10 shows their relationship up through 1954. The CAA estimate for 1965 of 8×10^8 ton-miles for air cargo must be based on aircraft types now in use. An additional curve

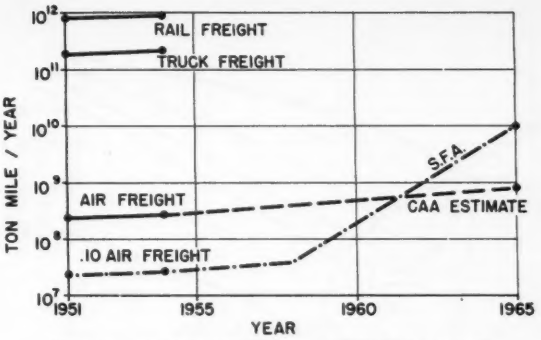

Fig. 10. Market assumption—short-field aircraft.

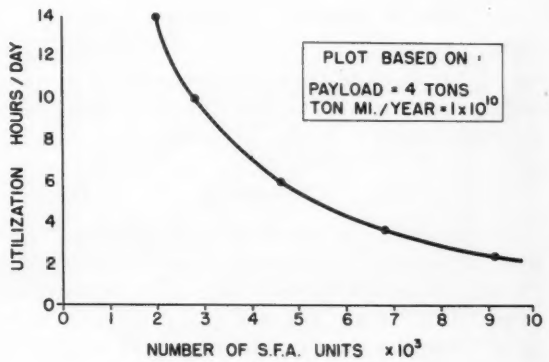

Fig. 11. Utilization vs. units.

0.10 AIR represents the assumed present market of short-range aircraft. Not until short-field aircraft become available will this lower curve begin to climb. This curve in 1965 is shown to have a volume of 10^{10} ton-miles. This is only 1 per cent of the combined rail and highway volume in 1954. By referring to Fig. 7, we can see that, for short-field aircraft to meet the volume quoted, a tariff of 10 cents/ton-mile must be charged.

As a means of measuring the capacity of short-field aircraft, Table 1 shows that the work capacity of a 4-ton payload unit is more than seven times greater than that of intercity trucks.

Thus, the equivalent of 2,740 short-field aircraft of 4-ton capacity will be required to move 10^{10} ton-miles of cargo per year.

Turnaround time is extremely important. As noted in Fig. 11, the capital invested in short-field aircraft units is directly related to utilization. This chart is another way of saying that a good integral palleting system can greatly reduce fleet size. It might be

Table 1

	Per Unit— Intercity Truck[5]	Short-Field Aircraft
Average load, tons	9.01	4
Average daily utilization, hours	5	10
Average speed, m.p.h.	30	250
Average daily mileage	150	2,500
Tons/year	2,204	14,600
Ton-miles/year	509,377	3,650,000

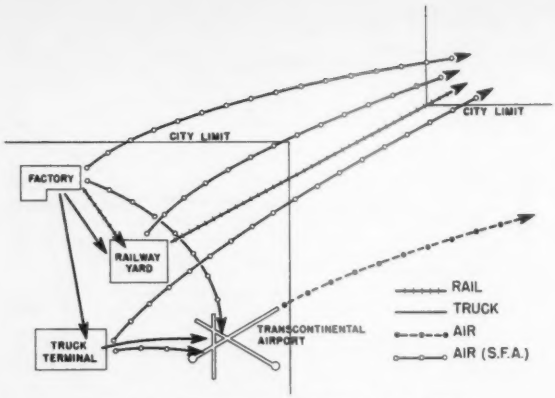

FIG. 12. Integration of short-field aircraft.

noted that an estimated 80 per cent of total in-transit time for air freight is consumed by slow and inefficient ground handling.

CONCLUSIONS

As the 550 m.p.h. transcontinental passenger transports now under development become operational in the near future, it will be necessary to improve mail and priority cargo movement at the local level. It is believed that the short-field airplane will supply the answer.

By analyzing market location, interrelation of volume and tariff, and possible design solutions and by estimating possible inroads on existing common carriers, this paper has shown the commercial air cargo potential over minimum distances. It is hoped that the points of view expressed will contribute to action and efforts leading to the stated conclusions.

Fig. 12 has been included as a graphical summary of the potential of short-field cargo aircraft in common carrier operation.

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Engineering Education (Continued from page 49)

more important than ever before for the more promising young men to seek training beyond the Bachelor degree.

CONCLUSIONS

We are in a technological race with Russia. The stakes are high because national survival is involved. While we cannot beat the Russians on quantity, we can compete on quality. In this connection it is to be noted that, although the Russians out-produce us more than two to one in engineers at the Bachelor's level, our output of men with a Master's degree in engineering is more nearly comparable, and at the Ph.D. level we equal or exceed the Russian production. This is significant since it is those with graduate training on whom we are coming to depend disproportionately for leadership and for creative advances. If we are going to win out over the Russians, or even to hold our own with them, it will be largely because of the efforts of engineers and scientists who achieved high standards as undergraduate students and then went on for graduate study at one of our universities.

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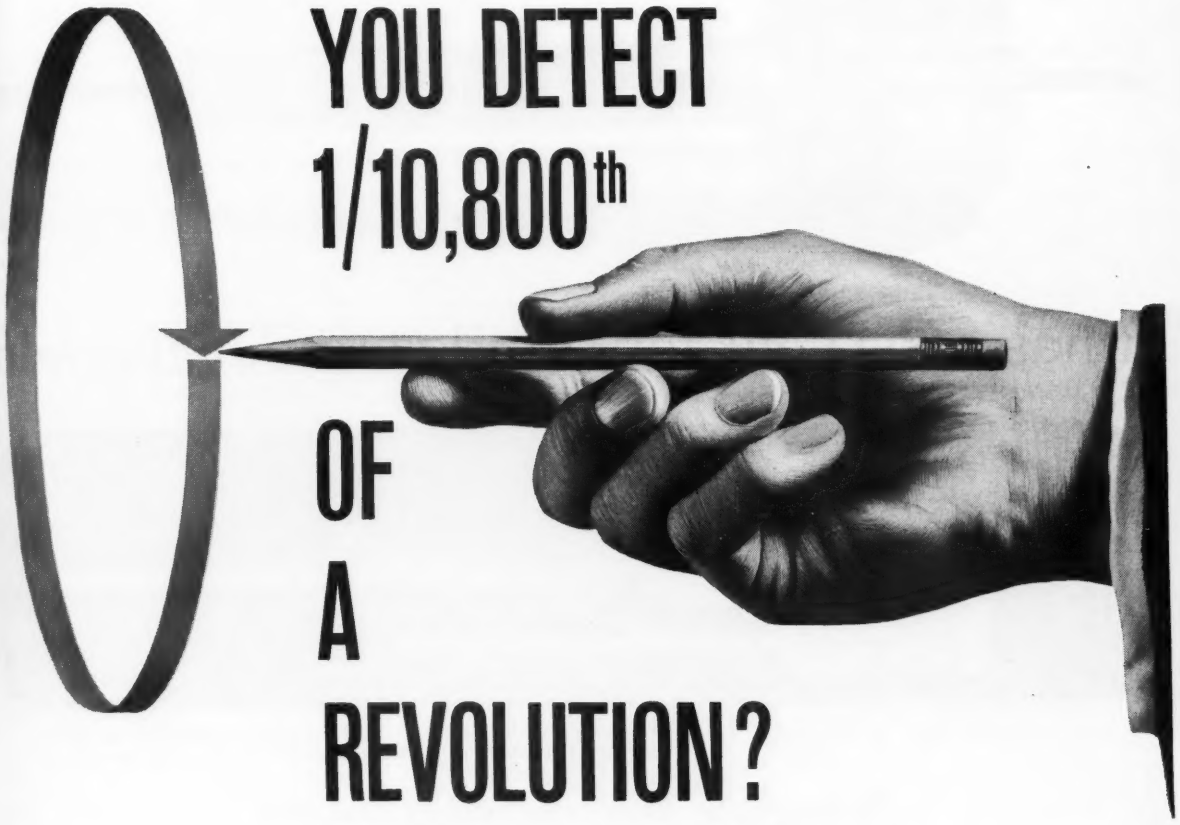

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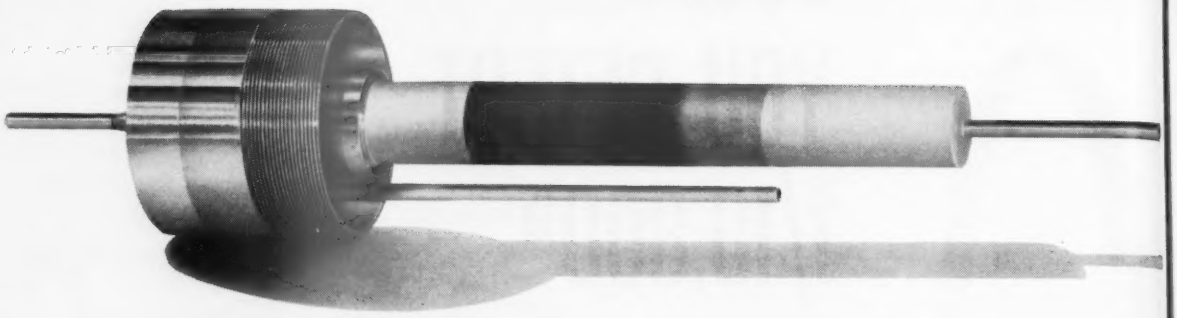
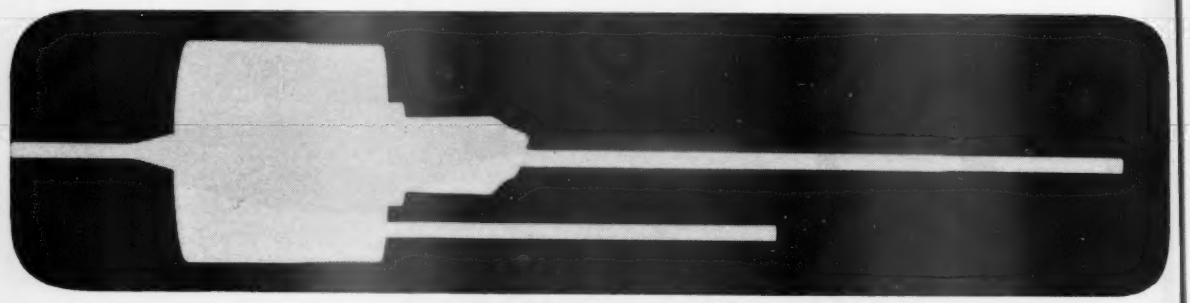
Seal unit of one of the repeaters of a transoceanic telephone cable



It has a 20-year job 3 miles under the sea



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Acoustics, Sound, Noise

On the Propagation of Plane Waves of Finite Amplitude. Z. A. Gol'dberg. *Sov. Phys.-Acous.*, Oct.-Dec., 1957, pp. 340–347. Translation. Analysis of the propagation of waves in viscous, thermally conducting medium from the point of view of acoustics of first and second approximations.

Diffraction and Radiation of Acoustic Waves in Fluids and Gases. I. M. D. Khaskind. *Sov. Phys.-Acous.*, Oct.-Dec., 1957, pp. 371–384. Translation. Discussion of the general theory of hydrodynamic forces which act on a body when diffraction and radiation of acoustic waves occur in fluids and gases.

Noise Exposure in Communities Near Jet Air Bases. A. C. Pietrasanta and K. N. Stevens. (*USAF WADC TN 57-10*, Apr., 1957.) *Noise Control*, Mar., 1958, pp. 29–36, 75.

KC-135 Noise Study. V. H. Marchbanks, Jr., and R. L. Slack. *Noise Control*, May, 1958, pp. 17–20, 52, 60. Measurement of noise levels in the after part of the fuselage during flight.

Review of Information on Jet Noise. P. A. Franken. *Noise Control*, May, 1958, pp. 8–16. 22 refs.

Novye Issledovaniia Shuma Tu-104 na Vzlete. V. Kvitka and G. Gubkina. *Grazhdanskaia Aviatsiia*, July, 1958, pp. 24, 25. In Russian. Further investigation of noise characteristics measured on the Tu-104 during take-off.

Reflection and Refraction of Sound by a Shock Wave. V. M. Kontorovich. (*Zhurnal Teoret. i Exper. Fiz.*, pp. 1, 527, 1, 528.) *Sov. Phys.-JETP*, June, 1958, pp. 1,180, 1,181. Translation. Analysis taking into account the perturbation of the surface of the shock wave.

Aerodynamics, Fluid Mechanics

Aerothermodynamics

Heat in High Places. *Shell Av. News*, July, 1958, pp. 14, 15. Description of investigations made by the NACA for minimizing the aerodynamic heating of missiles.

Heat Limits Hypersonic Flight. W. F. Radcliffe. *SAE J.*, July, 1958, pp. 86, 87. Discussion covering heat problems of hypersonic flight and means of removing heat from the leading edge.

Measurement of Turbulent Heat Transfer Rates on the Aft Portion and Blunt Base of a Hemisphere Cylinder in the Shock Tube. Josef Rabinowicz. (*GALCIT Memo. 41*, Nov. 1, 1957.) *Jet Propulsion*, Sept., 1958, pp. 615–620. 10 refs.

A Note on the Interaction of a Normal Shock Wave with a Thermal Boundary Layer. J. P. Appleton and H. J. Davies. *J. Aero/Space Sci.*, Nov., 1958, pp. 722, 723. Derivation of an alternative method yielding analytical expressions for the pressure and velocity perturbations.

Boundary Layer

Viscous Dissipation in Low Prandtl Number Boundary-Layer Flow. E. M. Sparrow and J. L. Gregg. *J. Aero/Space Sci.*, Nov., 1958, pp. 717, 718. Further analysis of the adiabatic-wall problem presented in the form of exact solutions of the boundary-layer energy equation and approximate solutions based on the von Kármán-Pohlhausen method.

Strato Limite Termico Attorno a una Lastra Piana Investita da una Corrente Lievemente Pulsante di Fluido Incompressibile. Silvio Gibellato. (*Atti Torino Accad. Sci.*, 1956–1957.) *Torino Polytech. Inst., Aero. Lab., Monograph 411*, Nov., 1956. 19 pp. In Italian. Study of the thermal boundary layer on a flat plate, with a calculation of temperature variations due to velocity fluctuations based on Blasius-Pohlhausen solutions for the stationary case.

Control Surfaces

Lateral Control at Supersonic Speeds by Means of Control Surfaces on Nacelles or on the Fuselage. D. W. Holder and R. C. Lock. *RAeS J.*, June, 1958, pp. 446–449. Description of a method for providing lateral control at supersonic speed. Results of calculations and measurements enabling the estimation of the effectiveness of such controls are given.

Flow of Fluids

Modelli di Macchine a Fluido. Modesto Panetti. *Tec. Ital.*, Mar., 1958, pp. 77–82. In Italian. Establishment of similarity laws for mechanical models using fluid substances, such as gas turbines and hydraulic systems, taking into account the effect of Mach Number and viscosity.

The Calculation of the Drag in Problems Solved by the Hodograph Method. (*Philos. Mag., 8th Ser.*, Feb., 1958, pp. 140–142.) *USAF OSR TN 58-640* [*AD 162129*], Feb., 1958. 3 pp.

O Sredakh, Dopuskaiushchikh Odnomernye Dvizheniia s Odnorodnoi Deformatsiei. A. G. Kulikovskii. *AN SSSR Dokl.*, May 21, 1958, pp. 485, 486. In Russian. Study of media in which plane motions with homogeneous deformations are possible.

Nekotorye Primery Dvizheniia Viazkogo Gaza v Uzkom Zazore Peremennoi Tolshchiny. Ia. M. Kotliar. *AN SSSR Otd. Tekh. Nauk Izv.*, May, 1958, pp. 34–39. In Russian. Study of the problem of motion of a viscous gas flowing through a narrow gap of varying thickness. Several illustrative examples are presented.

Exploratory Studies of Hypersonic Fluid Mechanics. S. M. Bogdonoff. (*NATO AGARD 11th Wind-Tunnel & Model-Testing Panel, Scheveningen, July 8–12, 1957.*) *NATO AGARD Rep. 142*, July, 1957. 29 pp. 22 refs. Review of studies made on simple two- and three-dimensional bodies in a helium tunnel at Mach Numbers from 11 to 19. Some preliminary results of boundary layer studies and dissolving models are also discussed.

Hypersonic Flow Characteristics Including Real Gas Effects. K. L. Goldman. *J. Aero/Space Sci.*, Nov., 1958, p. 728.

O Dvizheniiakh s Odnorodnoi Deformatsiei v Magnitnoi Gidrodinamike. A. G. Kulikovskii. *AN SSSR Dokl.*, June 11, 1958, pp. 984–986. In Russian. Presentation of a class of solutions for the equations of magnetohydrodynamics in the case of motion with homogeneous deformation.

Gasdinamica—Sulla Velocità di Dissociazione di un Gas Biatomico. Gianni Jarre. (*Rendiconti Accad. Naz. Lincei*, Sept.-Oct., 1957.) *Torino Polytech. Inst., Aero. Lab., Monograph 419*, Sept.-Oct., 1957. 10 pp. 12 refs. In Italian. AFEOARDC-sponsored discussion of the dissociation velocities of a biatomic gas.

On the Question of Molecular Gas Flow Through a Porous Membrane. S. P. Bakanov. *Sov. Phys.-Tech. Phys.*, July, 1957, pp. 1,503–1,505. Translation. Survey of previous investigations and study of the problem of gas flow at pressures where the purely molecular flow is definitely known to disappear.

Soluții Particulare ale Ecuației Scurgerii prin Medii Poroase Neomogene. T. Oroveanu. *Stud. Cerc. Mec. Aplic.*, No. 1, 1958, pp. 83–88. In Rumanian, with summaries in French and Russian. Derivation of solutions for the equation of flow through nonhomogeneous porous media.

Concerning the Stability of Shock Waves. V. M. Kontorovich. (*Zhurnal Teoret. i Exper. Fiz.*, Dec., 1957, pp. 1,525, 1,526.) *Sov. Phys.-JETP*, June, 1958, pp. 1,179, 1,180. Translation. Evaluation of previously obtained results and development of a method of calculation neglecting the transport of the perturbation of the moving fluid.

Stability of Shock Waves in Relativistic Hydrodynamics. V. M. Kontorovich. (*Zhurnal Teoret. i Exper. Fiz.*, Jan., 1958, pp. 186–194.) *Sov. Phys. JETP*, July, 1958, pp. 127–132. Translation. Investigation of the stability against small perturbations of the discontinuity surface for shock waves in an arbitrary medium, described by relativistic equations for an ideal fluid.

A Shock-Expansion Theory Applicable to Wings with Attached Shock Waves. L. M. Sheppard and K. D. Thomson. *Gt. Brit., ARC CP 392* (Jan., 1957) 1958. 17 pp. 10 refs. BIS, New York, $0.54.

Flow Properties Behind Strong Shock Waves in Nitrogen. H. F. Waldron. *J. Aero/Space Sci.*, Nov., 1958, pp. 719, 720.

Turbolenza di Parete. Carlo Ferrari. (*CIME Lecture, Varenna, Italy, Sept. 1–10, 1957.*) *Torino Polytech. Inst., Aero. Lab., Monograph 417*, Sept., 1957. 116 pp. 26 refs. In Italian. Investigation of wall turbulence, including simple cases of turbulent motion, boundary layer calculation, surface effect, and a survey of earlier research.

Internal Flow

Untersuchungen über die Strömungsverluste in ebenen Schaufelgittern. H. W. Hahnemann. *VDI Zeitschrift*, July 11, 1958, p. 864. In German. Brief survey of methods for studying flow losses in plane cascades.

Prüfstände zur Messung der Druckverteilung an rotierenden Schaufeln. K. Leist and W. Dettmering. *DVL Bericht No. 56*, June, 1958. 83 pp. 22 refs. Westdeutscher Verlag, Köln & Opladen. In German. Survey of test installations for measurement of pressure distribution on rotating blades, detailed description of the equipment developed by the Aachen Institute of turbomachines, and presentation of experimental results.

Two-Dimensional Flow Patterns at High Subsonic Speeds Past Wedges in Channels with Parallel Walls. J. B. Helliwell. (*J. Fluid Mech.*, Jan., 1958, p. 385.) *Royal Coll. Sci. & Tech. Dept. Math. TN 2* (*AFOSR TN 58-294*) [*AD 154203*], Jan., 1958. 19 pp.

On the Problem of Friction of a Stream of Water Against the Walls of a Nozzle at Ultrasonic Speeds. L. F. Vereshchagin, A. A. Semerchan, M. V. Maslennikov, and S. S. Sekoian. *Sov. Phys.-Tech. Phys.*, July, 1957, pp. 1,472, 1,473. Translation.

O Możliwościach Realizacji Przemiany Izotermicznej w Maszynach Przepływowych (Teoria Dyszy Isotermicznej). Jan Madejski. *Arch. Budowy Maszyn*, No. 2, 1958, pp. 157–176. In Polish, with summaries in English and Russian. Applications of isothermal nozzles in low and high temperature gas cycles.

Theory and Experiments on Supersonic Air-to-Air Ejectors. J. Fabri and J. Paulon. (*France, ONERA NT 36*, 1956.) *U.S., NACA TM 1410*, Sept., 1958. 30 pp. 11 refs. Translation.

Profile Aerodinamice cu Jet in Prezența Solului. Lucian Dumitrescu. *Stud. Cerc. Mec. Aplic.*, No. 1, 1958, pp. 43–49. In Rumanian, with summaries in French and Russian. Study of the problem of aerodynamic jet profiles in the presence of ground.

Die Tropfengrössen bei Drallzerstäubung. H. Gebhardt. *BWK*, Aug., 1958, pp. 361–366. 13 refs. In German. Experimental determination of drop size in the case of turbulent atomization.

Jet Flaps & Wings

An Assessment of the Jet Flap. J. H. Stevens. *Interavia*, Sept., 1958, pp. 958–961. Discussion of some of the more proeminent features of the jet flap system, and review of its development and possible applications.

Kilka Uwag o Płatach Strumieniowych. Antoni Tarnogrodzki. *Tech. Lotnicza*, May-June, 1958, pp. 63–70. 16 refs. In Polish. Discussion of the jet flap principle and description of some experimental results.

Recherches Expérimentales sur les Profils Aérodynamiques Soufflés. N. N. Patraulea, I. Dumitrescu, C. Popescu, D. Căpriță, and H. Gab. *Rev. Méc. Appl.*, No. 2, 1957, pp. 21–42. 14 refs. In French. Experimental investigation of jet flap profiles and presentation of results.

Caracteristicile Aerodinamice ale Profilelor cu Volet Fluid. N. N. Patraulea, L. Dumitrescu, and D. Căpriță. *Stud. Cerc. Mec. Aplic.*, No. 1, 1958, pp. 13–41. 13 refs. In Rumanian, with summaries in French and Russian. Development of a method for the calculation of aerodynamic characteristics of jet flaps. Includes determination of aerodynamic moments and the center of pressure for two specific cases.

Flight Tests of a Meteor Aeroplane Fitted with Jet Deflection. P. F. Ashwood and D. Lean. (*RAeS 31st Main Lecture, Bournemouth, Mar. 13, 1958.*) *RAeS J.*, Aug., 1958, pp. 539–558; Discussion, pp. 559–561. Survey of the development of the jet deflector and presentation of flight test results. Included are design features, thrust requirements, test instrumentation, and other experimental data.

Performance

Nekotorye Voprosy Teorii Poleta na Maksimal'nykh Skorostiakh i Vysotakh. A. M. Tarasenkov. *Vestnik Vozdushnogo Flota*, May, 1958, pp. 50–56. In Russian. Discussion of some problems of flight at optimum altitude and velocities, including fuel consumption, thrust, and other factors.

Najkorzystniejsze Warunki Wznoszenia Myśliwskich Samolotów Odrzutowych. Elemér Rácz and Ladislaus Varga. *Tech. Lotnicza*, May-June, 1958, pp. 78–82. In Polish. Determination of the optimum climbing conditions for jet aircraft.

A Method for Providing Warning of the Onset of Buffeting, Stalling and Other Undesirable Effects of Flow Separation. D. W. Holder and H. H. Pearcey. *RAeS J.*, Sept., 1958, pp. 674–676. Description of a method, based on static pressure measurements near the trailing edge, to provide warning of the onset of undesirable effects produced by flow separation on an aircraft wing.

Stability & Control

Probleme Vechi și Noi în Teoria Stabilității și Maniabilității Avionului. T. Hacker. *Rev. Transp.*, Aug., 1958, pp. 373–378. 10 refs. In Rumanian. Review of current problems of aircraft stability.

A Simplified Method for Approximating the Transient Motion in Angles of Attack and Sideslip During a Constant Rolling Maneuver. Leonard Sternfield. *U.S., NACA Rep. 1344*, 1958. 11 pp. Supt. of Doc., Wash., 0.20.

Wings & Airfoils

Flussi Transonici Attorno a Profili Alari Simmetrici, con Onda d'Urto Staccata. Silvio Nocilla. (*Atti Torino Accad. Sci.*, 1956–1957.) *Torino Polytech. Inst., Aero. Lab., Monograph 414*, Apr., 1957. 33 pp. In Italian. AFEOARDC-sponsored investigation of transonic flow around symmetrical airfoil profiles with detached shock waves.

A Technique for Improving the Predictions of Linearised Theory on the Drag of Straight-Edged Wings. D. G. Randall. *Gt. Brit., ARC CP 394* (Jan., 1957) 1958. 41 pp. BIS, New York, $1.08.

Ecoulements Coniques d'Ordre Supérieur Autour d'une Aile Triangulaire à Plaque Normale. Elie Carafoli and Béatrice Horovitz. *Rev. Méc.*

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INTERNATIONAL AERONAUTICAL ABSTRACTS

A Review of Worldwide Scientific and Technical Literature

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AERODYNAMICS, FLUID MECHANICS

Aerothermodynamics

BOUNDARY LAYERS WITH CHEMICAL REACTIONS DUE TO MASS ADDITION. C. B. Cohen, R. Bromberg, and R. P. Lipkis. Jet Propulsion, Oct., 1958, pp. 659-668. Analysis concerning the essential effects of chemical reactions involving sublimated or injected gases within the boundary layer upon the amount of heat transferred to the ablating or porous surface. In this treatment, the diffusion coefficients of all species are assumed equal and the "frozen" Prandtl and Lewis moduli are taken to be unity. Solutions are given for three problems: (a) a diffusion-limited irreversible reaction, typified by the oxidation of carbon to carbon monoxide; (b) a temperature-limited irreversible reaction, such as dissociation without recombination; and (c) a reversible reaction including complete dissociation and recombination within the boundary layer.

HEAT TRANSFER IN BOUNDARY LAYERS WITH CHEMICAL REACTIONS DUE TO MASS ADDITION. R. Bromberg and R. P. Lipkis. Jet Propulsion, Oct., 1958, pp. 668-674. Review of the essential features of the differential equations applicable in the boundary layer with mass transfer at the wall, including considerations of chemical reactions. A brief derivation is given, and the equations are presented in the alternate forms useful for various applications. Special discussion is given on the wall boundary conditions because of possible confusion arising from effects of mass transfer at the wall. A general formal solution to these equations is obtained which makes it possible to determine the heat transfer potential, subject only to the requirement that Lewis Number equal unity. No limitation is placed on reaction rates or other details of the reaction, or on the Prandtl Number. Solutions are presented for the case of combustion of carbon to CO, and for the dissociation and recombination within the boundary layer of an injected material.

EVAPORATION INTO A BOUNDARY LAYER. Ernest Bauer and Martin Zlotnick. Phys. Fluids, July-Aug., 1958, pp. 355, 356. Analysis to determine the evaporation rates of a solid or liquid into a stream of gas flowing across a surface, considered as a function of surface temperature and material and gas properties, neglecting chemical reactions. One of the boundary conditions to be used at the interface between the gas and the solid (or liquid) is derived.

MASS TRANSFER COOLING NEAR THE STAGNATION POINT. Appendix - FLOW WITHIN THE POROUS WALL. Leonard Roberts. US, NACA TN 4391, Sept., 1958. 42 pp. Presentation of a simplified analysis to determine the effect on heat transfer of injection of air or a foreign gas. The reduction in heat transfer is given in terms of the properties of the coolant gas, and it is shown that it may be reduced considerably by the introduction of a gas having appropriate thermal and diffusive properties. The mechanism of heat transfer reduction is discussed. Conclusions show that maximum boundary-layer shielding is achieved when the gas of higher specific heat is convected in the hot fast-moving part of the boundary layer farthest from the wall.

PRELIMINARY HEAT-TRANSFER STUDIES ON TWO BODIES OF REVOLUTION AT ANGLE OF ATTACK AT A MACH NUMBER OF 3.12. Norman Sands and J. R. Jack. US, NACA TN 4378, Sept., 1958. 29 pp. Investigation of the effects that angle of attack has on the heat-transfer characteristics of a cone cylinder and parabolic-nosed cylinder. For similar type boundary layers Stanton Numbers at angles of attack are always higher than those of corresponding geometric location and test conditions at zero angle of attack. On the windward side Stanton Numbers increased steadily with increasing angle of attack. Along the most leeward generator no systematic variation of Stanton Number with angle of attack is found. The parabolic forebody has two advantages over the conical forebody - it delays transition and reduces local Stanton Numbers.

THE EFFECT OF FREE-STREAM TURBULENCE ON HEAT TRANSFER FROM A FLAT PLATE. Sugao Sugawara, Takashi Sato, Hiroyasu Komatsu, and Hiroichi Osaka. (Japan Soc. Mech. Eng. J., No. 18, 1953, pp. 18-25.) US, NACA TM 1441, Sept., 1958. 21 pp. Translation. Measurements of the local heat-transfer coefficients at 12 different locations along the plate for the cases of various turbulence levels. The transition Reynolds Number from laminar to turbulent flow decreases as the main-stream turbulence level increases. In the range of laminar heat transfer the effect of turbulence in the main flow is not great, but in the range of turbulent heat transfer the heat-transfer coefficient increases according to the increase of turbulence.

TRANSIENT TEMPERATURE DISTRIBUTION IN A TWO-COMPONENT SEMI-INFINITE COMPOSITE SLAB OF ARBITRARY MATERIALS SUBJECTED TO AERODYNAMIC HEATING WITH A DISCONTINUOUS CHANGE IN EQUILIBRIUM TEMPERATURE OR HEAT-TRANSFER COEFFICIENT. R. L. Trimpi and R. A. Jones. US, NACA TN 4308, Sept., 1958. 83 pp. Derivation of a solution in the form of an infinite analytic series. The first six terms of the series are evaluated numerically and tabulated in a form to permit easy computation of heat-transfer problems typical to aerodynamic testing. Analytical results obtained from these solutions can be used to determine (a) the heat-transfer testing time for which the outer skin may be assumed to act as a calorimeter without exceeding a given error, or (b) correction curves by which the indicated calorimeter heat-transfer coefficient may be multiplied to obtain the true heat-transfer coefficient. The problem of continuously varying equilibrium temperatures and heat-transfer coefficients may be treated by using the tabulated solutions and considering the continuous variation as a series of superimposed step functions.

Boundary Layer

SIMULTANEOUS EFFECTS OF PRESSURE GRADIENT AND TRANSVERSE CURVATURE ON THE BOUNDARY LAYER ALONG SLENDER BODIES OF REVOLUTION. Appendix A - NUMERICAL INTEGRATION OF THE ZEROTH ORDER MOMENTUM EQUATION FOR A PARABOLOID. Appendix B - NUMERICAL INTEGRATION OF THE FIRST ORDER MOMENTUM EQUATION FOR A PARABOLOID. Michiru Yasuhara. Tokyo U. Aero. Res. Inst. Rep. 335, Aug., 1958. 17 pp. Presentation of two methods of calculation: the first is the perturbation expansion of flow quantities from the uniform state, and the second is that from the stagnation state. In both cases allowable body shapes are obtained for the given outer pressure gradient. As an example of the first method, the boundary layer flow along a slender paraboloid of revolution is calculated. The results show that, as found previously, the transverse curvature acts on the flow somewhat similarly as a favorable pressure gradient. The displacement and the longitudinal curvature effects on the viscous layer are also estimated. These effects are found to appear in the second-order terms of the series expansion.

SOME DETAILS OF THE QUINTIC PROFILE FOR USE IN THE POHLHAUSEN-TYPE OF BOUNDARY-LAYER CALCULATION. N. Curle. Gt. Brit., ARC CP 391, 1958. 8 pp. BIS, New York, $0.27. Development of a general theory for a quintic profile satisfying an additional boundary condition at the wall. A detailed analysis is given for the case of a linearly retarded mainstream; good agreement is obtained upon comparison with the exact solution.

MEASUREMENTS OF THE BOUNDARY LAYER THICKNESS AND RELAXATION OF IONIZATION BEHIND STRONG SHOCK WAVES WITH A NEW CAPACITIVE PROBE. H. Groenig and H. D. Weymann. Aachen Tech. Hochschule Inst. Mech. TN 1 (EOARDC TN 58-387) [AD 154294], Feb., 1958. 22 pp. Measurement of the thickness of the boundary layer, the relaxation time of ionization, and the coefficient of diffusion in high temperature argon behind strong shock waves at Mach Numbers between 5 and 10 with a new capacity probe. This probe is inserted flush into the wall of the shock tube, thus avoiding any disturbances in the flow, and is sensitive to the thickness of the boundary layer when the gas in the undisturbed flow is ionized. The shock tube and the processes behind the shock front are described. A theoretical discussion of the boundary layer, ionization, and diffusion of ions is made. Typical photographic records of the oscilloscope traces are shown.

SIMILAR SOLUTIONS FOR THE COMPRESSIBLE BOUNDARY LAYER ON A YAWED CYLINDER WITH TRANSPIRATION COOLING. Appendix A - DERIVATION OF SIMPLIFIED BOUNDARY-LAYER EQUATIONS. Appendix B - INTEGRAL EQUATIONS IN TRANSFORMED PLANE. Appendix C - UNIQUENESS OF SOLUTIONS FOR NEGATIVE VALUES OF β . I. E. Beckwith. US, NACA TN 4345, Sept., 1958. 72 pp. 27 refs. Development of general equations for the heat transfer and skin friction in the laminar compressible boundary layer on infinite cylinders in yaw for the case in which the velocity and enthalpy profiles are functions of similarity variable. By means of numerical solutions of the boundary-layer equations, the effects of transpiration cooling, Prandtl Numbers, and viscosity relations are obtained for stagnation-line flow. The effect of chordwise pressure gradient is investigated for a nonporous wall, a Prandtl Number of one, and a linear viscosity-temperature relation.

A NONLINEAR THEORY FOR PREDICTING THE EFFECTS OF UNSTEADY LAMINAR, TURBULENT, OR TRANSITIONAL BOUNDARY LAYERS ON THE ATTENUATION OF SHOCK WAVES IN A SHOCK TUBE WITH EXPERIMENTAL COMPARISON. R. L. Trimpi and N. B. Cohen. US, NACA TN 4347, Sept., 1958. 105 pp. 21 refs. Presentation of the following modifications to a previously developed linearized attenuation theory: (a) an unsteady compressible local skin-friction coefficient is employed rather than the equivalent

steady-flow incompressible coefficient; (b) a nonlinear approach is used to permit application of the theory to large attenuation; and (c) transition effects are considered. Curves are presented for predicting attenuation for shock pressure ratios up to 20 and a range of shock-tube Reynolds Numbers. Comparison of theory and experimental data for shock-wave strengths between 1.5 and 10 over a wide range of Reynolds Numbers shows good agreement with nonlinear theory.

LARGE-SCALE WIND-TUNNEL TESTS OF AN AIRPLANE MODEL WITH AN UNSWEPT, ASPECT-RATIO-10 WING, TWO PROPELLERS, AND AREA-SUCTION FLAPS. J. A. Weiberg, R. N. Griffin, Jr., and G. L. Florman. US, NACA TN 4365, Sept., 1958. 76 pp. 12 refs. Investigation to determine the effects of a propeller slipstream on the lift obtainable and the flow requirements for suction applied to the porous area of a trailing edge flap. The lift increment produced by the propeller slipstream increased approximately in proportion to the slipstream velocity. The propeller slipstream had no effect on the suction flow requirements, but the suction pressures required increased with thrust coefficient approximately in proportion to the slipstream velocity. Comparisons with results of tests on the same model but having a combination slot suction and ailerons indicated considerably lower suction flow requirements for the area-suction flaps.

OBSERVATIONS SUR LA TRANSITION LAMINAIRE-TURBULENT EN TROIS DIMENSIONS. E. A. Eichelbrenner and R. Michel. La Recherche Aéronautique, July-Aug., 1958, pp. 3-10. 11 refs. In French. Investigation of the three-dimensional boundary-layer transition, including analysis of empirical and semiempirical criteria and application to a body of revolution at incidence. It is shown that the most important factors are (a) longitudinal instability defined by Tollmien-Schlichting and generalized by Michel's criterion and (b) transversal stability of the Rayleigh type defined by Owen's criterion. A form of irregularity is observed on ellipsoidal bodies at the transition region, implying a type of influence not accounted for by the analyzed factors of (a) and (b).

APPROXIMATE METHOD FOR CALCULATING THE LAMINAR BOUNDARY LAYER OF BODIES WITH OUTFLOW. W. Gohrbandt. Gt. Brit., NGTE Rep. R.224, June, 1958. 58 pp. 23 refs. Extension of the Pohlhausen method to the calculation of the velocity field for two- and three-dimensional bodies with outflow from the surface. The von Kármán momentum equation for the boundary layer is used as the starting point and, by introducing Pohlhausen's expression for the velocity distribution within the boundary layer, it is found that for the particular outflow law, where the outflow varies inversely as the boundary layer thickness, the computation is simplified. Calculations are then carried out for this special outflow law for spheres using both the potential flow and the experimental pressure distribution. A range of negative outflow - i.e., suction, is also investigated, and it is found that the Pohlhausen expression fails in this case.

AN INVESTIGATION OF SUPERSONIC TURBULENT BOUNDARY LAYERS ON SLENDER BODIES OF REVOLUTION IN FREE FLIGHT BY USE OF A MACH-ZEHNDER INTERFEROMETER AND SHADOWGRAPHS. Appendix - EFFECT OF LIGHT REFRACTION ON THE ACCURACY OF BOUNDARY-LAYER-THICKNESS MEASUREMENTS FROM SHADOWGRAPHS. Alvin Seiff and B. J. Short. US, NACA TN 4364, Sept., 1958. 57 pp. 18 refs. Measurement of the density distribution in supersonic turbulent boundary layers with large heat transfer. Fluctuations of air density in these boundary layers are observed. The mean density distributions are compared with those given by the Crocco equation, and the mean heat transfer is computed from an energy balance and compared with that given by the modified Reynolds analogy.

Control Surfaces

EFFECTS OF PROPELLER POSITION AND OVERLAP ON THE SLIPSTREAM DEFLECTION CHARACTERISTICS OF A WING-PROPELLER CONFIGURATION EQUIPPED WITH A SLIDING AND FOWLER FLAP. W. C. Hayes, Jr., R. E. Kuhn, and I. R. Sherman. US, NACA TN 4404, Sept., 1958. 81 pp. Investigation in a static-test facility including the effects of a leading-edge slat, nacelle size, flap segmentation, and number of propellers. Results indicate that lowering the thrust axis reduces the diving moments by virtue of the direct moment applied when the thrust vector passes below the moment reference point. Little or no change in the aerodynamics of the configuration arising from either vertical or chordwise changes in the position of the propeller was noted. Overlapping the propellers produced significant increases in thrust recovery at the highest flap deflection; however, these gains were greatly reduced by a corresponding loss in propeller static-thrust efficiency.

Flow of Fluids

EIN NEUES CHARAKTERISTIKENVERFAHREN FÜR EINDIMENSIONALE INSTATIONÄRE STRÖMUNGEN. J. Teipel. DVL Bericht No. 74, Aug., 1958. 37 pp. Westdeutscher Verlag, Köln & Opladen. In German. Development of a method of characteristics for one-dimensional nonstationary linear flows. Few illustrative examples are presented and the influence of cross-sectional modification on nonstationary waves is determined, thus indicating that a part of the wave is being reflected. It is also shown how a line of discontinuity, having a different entropy at each side, passes through a Laval nozzle.

ON THE NATURE OF STALL. S. J. Kline. Stanford U., Dept. Mech. Eng. Rep. MD-4 (AFOSR TN 58-637) [AD 162168], June, 1958. 72 pp. 33 refs. Discussion of the problem of flow in passages, including few comparisons with external flow and a review of available physical stall

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data. The emphasis is placed on systematic visual data showing flow patterns as a function of geometric parameters. These data lead to a view of stall as a spectrum involving three or possibly four major types of flow patterns; these involve both transient and steady elements. A qualitative parameter is formulated, providing a classification for the major types of stall. Some experiments performed for verifying the concepts inherent in this parameter are described. Comparison between the predictions of boundary-layer theory and the actual systematic stall data of passages are given. The reasons for the discrepancies existing in the predicted location and trends of stall inception are also discussed.

KINETIC THEORY OF THE IMPULSIVE MOTION OF AN INFINITE PLANE. E. P. Gross and E. A. Jackson. Phys. Fluids, July-Aug., 1958, pp. 318-328. 19 refs. AFOSR-supported application of a half-range method of solution for the Boltzmann equation in order to give a kinetic theory treatment of the Rayleigh problem. In contrast to the Navier-Stokes or Grad theories, the method yields exact results for the initial stress and slip velocity at the boundary. It also indicates corrections to the classical Rayleigh results, even at long times compared to the collision periods of the gas molecules. The corrections are shown to be related to the usual slip boundary conditions of hydrodynamics plus an additional part arising from boundary layer effects.

HYPERSONIC VISCOUS FLOW OVER SLENDER CONES. Appendix A - NUMERICAL-GRAPHICAL METHOD FOR CALCULATING SELF-INDUCED PRESSURES ON CONE SURFACE. Appendix B - PROBSTEIN'S ANALYSIS FOR SELF-INDUCED-PRESSURE EFFECT. Lawrence Talbot, Toyoki Koga, and P. M. Sherman. US, NACA TN 4327, Sept., 1958. 34 pp. 28 refs. Measurement of various self-induced pressures on 3°-semivertex-angle cones. The data are found to be in good agreement with results obtained by Talbot on 5° cones and to correlate reasonably well by the viscous-interaction parameter $\bar{\chi}_c$. Includes presentation of an approximate method for calculating self-induced pressures which takes into account the interaction between boundary-layer growth and the inviscid-flow field at the outer edge of the boundary layer. Pressures calculated by this method are 10% to 20% higher than the measured values.

FORCE AND PRESSURE MEASUREMENTS AT TRANSONIC SPEEDS FOR SEVERAL BODIES HAVING ELLIPTICAL CROSS SECTIONS. J. B. McDevitt and R. A. Taylor. US, NACA TN 4362, Sept., 1958. 152 pp. Presentation of force data and surface-pressure distributions at angles of attack from 0° to 6° for a series of bodies having elliptical cross sections with ratios of major-to-minor axes of 1.0, 1.5, 2.0, and 3.0. All the bodies had identical axial distributions of cross-section area. The Ames 14-ft. transonic wind tunnel used for the investigation and the test procedures are described. Pressure distributions for the surrounding flow fields are presented for the various bodies at zero angle of attack. The Mach Number range varied from 0.8 to 1.2, and the Reynolds Number was approximately 24×10^6.

THEORETICAL INVESTIGATION OF THE FLOW FIELD ABOUT BLUNT-NOSED BODIES IN SUPERSONIC FLIGHT. Roberto Vaglio-Laurin and Antonio Ferri. J. Aero/Space Sci., Dec., 1958, pp. 761-770. 13 refs. Development of a numerical method to obtain a solution for the inverse problem of the flow behind a given detached shock to any desired accuracy. The cases of zero and small incidence are considered. The combination of sets for such solutions satisfying prescribed boundary conditions is described. Particular attention is devoted to the analysis of the sonic and subsonic region of the flow field. Convergence and stability of the stepwise integration from the shock in the elliptic region are discussed.

DATEN EINER DREIPARAMETRIGEN SYSTEMATIK VON ROTATIONSHALBKÖRPERN FÜR DIE STRÖMUNGSVERHÄLTNISSE BEI SCHALLANSTRÖMUNG UND LINEARISIERTER ÜBERSCHALLSTRÖMUNG. W. Schmidt. DVL Bericht No. 70, Aug., 1958. 42 pp. Westdeutscher Verlag, Köln & Opladen. In German. Establishment of a three parametric scheme for slender half bodies of revolution. Data are presented for sonic and linearized supersonic flow conditions, as well as wave drag data at any body length at $M_\infty = 1$, with a detailed table of numerical values. The case of a half body of revolution having minimum drag is also considered. The shocks which may occur at the body are not included in the calculation.

OGIVE HAVING MINIMUM DRAG IN TWO-DIMENSIONAL HYPERSONIC FLOW. Ennio Mattioli. Torino Polytech. Inst. Appl. Mech. Lab. TN 8 (AFOSR TN 58-640) [AD 162171], June, 1958. 30 pp. 14 refs. Determination of a minimum-drag ogive in an inviscid fluid at zero incidence for the separate cases of a given thickness, a given arc length, or a given enclosed area. The fluid is assumed inviscid and the airfoil symmetric with zero incidence. The flow behind the shock wave is considered a quasi-simple wave if the hypersonic similarity parameter does not reach the value of 2. This is vigorously demonstrated in the proximity of the shock wave on the leading edge by a comparison between pressure coefficients. Because the entropy gradient and rotationality are the greatest in this region, it is assumed the approximation has a general character over the whole field.

FLOW PAST A BENT FLAT PLATE WITH AN UNSYMMETRIC DEAD AIR AT MACH NUMBER 1. Takeo Sakurai. Phys. Soc. Japan J., Sept., 1958, pp. 1, 055-1, 060. 12 refs. Analysis of the ideal case of flow past a bent plate in which the streamline comes tangentially to the plate at the leading edge, using Imai's WKB method. Numerical results are given for several values of the form parameter α. The comparison of $C_{L(\text{exact})}$ and the modified C_L shows that the approximation is comparatively good for the small value of α, but becomes worse as α increases.

ON THE MOTION OF TWO CYLINDERS IN AN IDEAL FLUID. L. H. Carpenter. J. Res., Aug., pp. 83--87. ONR-sponsored determination of the motion of two cylinders in an infinite liquid by the method of image doublets; the solution is expressed as an infinite series in rectangular coordinates. Approximate solutions in finite form are given for various cases. A method for generalizing the solution for the case of more than two cylinders is indicated. Applications to the flow induced by a cylinder moving in the presence of plane boundaries are given, and the stream lines are illustrated in certain cases.

THE FLOW WITH WAKE PAST AN OBLIQUE PLATE. Yōichi Mimura. Phys. Soc. Japan J., Sept., 1958, pp. 1,048-1,055. Calculations of the pressure distribution on the front surface of the plate, as well as on the free streamlines, for the case of two-dimensional flow with wake of a perfect fluid past an oblique plate by applying the method of notched hodograph devised by Roshko. The calculated values are compared with those obtained experimentally by Fage and Johansen. It is thus found that the calculated and observed values of the pressure distribution along the front surface of the plate coincide fairly well with each other so far as the observed base pressure is constant, but discrepancies between them increase as the angle of attack decreases.

EXPERIMENTAL INVESTIGATION OF TRANSPIRATION COOLING IN TURBULENT PIPE FLOW. S. W. Yuan and A. Barazotti. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 479, Aug., 1958. 39 pp. 24 refs. USAF-Navy-sponsored experimental investigation of the effect of coolant air injection at the wall on the velocity and temperature distributions of the turbulent flow in a porous-wall pipe. Experimental equipment and procedure are described, and the range of flow conditions is presented. Satisfactory agreement exists between theoretical results and experimental data. It is shown that the wall-friction coefficient increases with the increase of coolant injection, whereas the heat transfer coefficient decreases. Thus, the analogy between the heat transfer and momentum transfer does not exist in transpiration cooling of pipe flow.

AERODYNAMIC DISSIPATION. H. E. Petschek. Avco Res. Lab. RR 23, June, 1957. 21 pp. 11 refs. USAF-sponsored discussion of dissipation in an ionized gas in the presence of a magnetic field. The derivation of the basic flow equations is reexamined, and the difference of the basic microscopic dissipation mechanism demonstrated. It is shown that the minimum length in which the properties of the flow can change noticeably is appreciably less than one mean free path. To derive hydrodynamic equations two Boltzmann equations are used, one for the electrons and one for the ions, coupled with the four Maxwell equations which describe the electromagnetic field. The steepening of a pressure pulse into a shock wave is considered. Experiments performed with the aim of studying gas dynamics in the M region are briefly discussed.

SMALL PERTURBATIONS IN HYDROMAGNETICS, FREE OSCILLATIONS IN A RECTANGULAR BOX, AND THE PERFECTLY CONDUCTING GAS. G. S. S. Ludford. U. Md. Inst. Fluid Dynamics & Appl. Math. TR BN-143 (AFOSR TN 58-700)[AD 162234], July, 1958. 23 pp. Analysis of the small perturbations of an electrically conducting inviscid gas in the presence of a uniform undisturbed magnetic field. The free oscillations in a rectangular box are determined and used to examine the limit of infinite conductivity. Plane waves are discussed. The system of first-order linear differential equations governing the motion is considered. It is shown that by suitable transformation the general perturbation equations can be split into sets of four and five, each set leading to a partial differential equation of the same order. The standing waves in the fluid confined in a rectangular perfectly conducting box, into which a uniform magnetic field perpendicular to two of the faces has been frozen, is examined; these waves are of three types. The limiting forms of the waves for two extreme cases are discussed. The general initial-value problem and the determination of Fourier coefficients appropriate to the orthogonal system defined by the standing waves are also discussed.

DYNAMIC STABILITY OF A SELF-PINCHED DISCHARGE. H. W. Wyld, Jr. J. Appl. Phys., Oct., 1958, pp. 1,460-1,465. Study of the stability of a rapidly contracting self-pinched discharge using three different models for the plasma dynamics: the free particle model, the snowplow model, and the shock wave model. For each model the growth in time of a small perturbation on a time-dependent unperturbed solution of the equations of motion is obtained. It is shown that the free particle model and the shock wave model predict instabilities, and that an initially small perturbation becomes large in times comparable to the pinch time. The snowplow model predicts stability for the initial stages of the pinch, although instabilities probably develop later on.

STABILITY OF THE STATIONARY CONVECTIVE FLOW OF AN ELECTRICALLY CONDUCTING LIQUID BETWEEN PARALLEL VERTICAL PLATES IN A MAGNETIC FIELD. G. Z. Gershuni and E. M. Zhukhovitskii. (Zhurnal Teoret. i Exper. Fiz., Mar., 1958, pp. 675-683.) Sov. Phys. - JETP, Sept., 1958, pp. 465-470. Translation. Investigation of the effect of a constant magnetic field on the hydrodynamic stability of flow. The equations for the amplitudes of the perturbations are solved by approximations, using the method of Galerkin. The study shows that a magnetic field greatly increases the stability of the stationary flow. In the case of a longitudinal field, the instability is always in the form of a "standing" perturbation. The critical Grasshof Number and the critical wave number for standing and running perturbations have been determined as functions of the field strength.

AXISYMMETRIC STAGNANT FLOW OF A VISCOUS AND ELECTRICALLY CONDUCTING FLUID NEAR THE BLUNT NOSE OF A SPINNING BODY

WITH PRESENCE OF MAGNETIC FIELD. I - EXACT SOLUTION OF INCOMPRESSIBLE AND CONSTANT-PROPERTIES MODEL. Ching-Sheng Wu and W. D. Hayes. Princeton U. Dept. Aero. Eng. Rep. 431 (AFOSR TN 58-405) [AD 158208], Apr., 1958. 46 pp. 11 refs. Determination of the velocity and temperature fields for the flow of a viscous and electrically conducting fluid in the vicinity of the stagnation point of a blunt-nosed body with an applied magnetic field fixed relative to it. The body of revolution is axisymmetric, and the fluid is assumed to be incompressible and has constant physical properties. The final differential systems contain one principal system and two subordinate systems. It is concluded that the magnetic Reynolds Number is as important as the viscous Reynolds Number and magnetic pressure number in the discussion of approximate method of solution.

ENERGY TRANSFER THROUGH A DISSOCIATED DIATOMIC GAS IN COUETTE FLOW. J. F. Clarke. J. Fluid Mech., Sept., 1958, pp. 441-465. 19 refs. Analysis of the energy transfer using values appropriate to oxygen for numerical illustrations. The two extremes of chemical equilibrium flow and chemically frozen flow are dealt with in detail, and it is shown that the surface reaction rate is of prime importance in the latter case. The chemical rate equations in the gas phase are used to estimate the probable chemical state of the gas mixture. For practical values of the surface reaction rate on a metallic wall, the energy transfer rate may be significantly lower in chemically frozen flow than in chemical equilibrium flow under otherwise similar circumstances. The influence of the surface reaction appears to spread out into the shear layer as homogeneous reaction rates decrease.

ENERGY CONTENT AND IONIZATION LEVEL IN AN ARGON GAS JET HEATED BY A HIGH INTENSITY ARC. G. L. Cann and A. C. Ducati. J. Fluid Mech., Sept., 1958, pp. 529-537. Development of a direct current electric heating device for argon gas. Under normal conditions 50% to 90% of the input electric power is transferred directly to the gas, the remaining being absorbed by the water-cooled electrodes. Measurements are made to determine the total gas enthalpy and the proportion of the enthalpy in directed kinetic energy, random particle motion, and ionization energy.

A NOTE ON SHOCK FLOW IN A CHANNEL. Roy Gundersen. J. Fluid Mech., Sept., 1958, pp. 501-504. Discussion of the nonsteady flow in a channel of slowly converging or diverging cross-section, linearized with respect to small area variations. A shock is produced by a uniform compressive piston motion and passes into a channel of slowly varying cross-section. A relation between shock strength and the area of the channel, is obtained in closed form and used to discuss converging cylindrical and spherical shocks.

O NEKOTORYKH TOCHNYKH RESHENIIAKH URAVNENII GAZOVOI DINAMIKI. S. S. Grigorian. AN SSSR Dokl., Aug. 1, 1958, pp. 606-609. In Russian. Analysis of certain exact solutions for the equations of nonstationary gas dynamics used to solve the following problems: (a) the possibility of a motion of an ideal non-heat-conducting gas with a shock wave producing a region behind the wave in which the speed of sound is not zero and where, in the case of turbulent motion, the perturbations will not overtake the shock wave; (b) the possibility of generating in the same region a second shock wave which will propagate but never overtake the first wave.

ON PITOT PRESSURE IN AN ALMOST-FREE-MOLECULE FLOW - A PHYSICAL THEORY FOR RAREFIED-GAS FLOWS. V. C. Liu. J. Aero/Space Sci., Dec., 1958, pp. 779-785. 18 refs. Development of a physical theory of pitot pressure in the transition-flow regime. The ratio λ/b (the mean free path to the radius of the cavity opening) is assumed to be of the order unity or larger. A general formula for the perturbation to the pitot pressure in the free-molecule flow is given. This perturbation is attributed to the intermolecular collisions which are neglected on the basis of the free-molecule hypothesis. The expected rate of collision is calculated for rigid spheres using the classical kinetic theory.

RELATION BETWEEN TIME SYMMETRY AND REFLECTION SYMMETRY OF TURBULENT FLUIDS. W. C. Meecham. Phys. Fluids, Sept.-Oct., 1958, pp. 408-410. Study showing that, on the basis of an assumption of statistical reflection symmetry for certain turbulent flows, some space-time velocity correlations characterizing the flow are even functions of the time delay between the correlation measurements. In particular, the second- and one of the fourth-order velocity correlations are symmetric in this relative time.

ON THE DISTURBED MOTION OF A PLANE VORTEX SHEET. J. W. Miles. J. Fluid Mech., Sept., 1958, pp. 538-552. 10 refs. Development of a formal solution to the initial value problem for a plane vortex sheet in an inviscid fluid by transform methods. The eigenvalue problem is investigated and the stability criterion determined. Results confirm those of Landau, Hatanaka, and Pai with respect to stability, but rule out certain of their neutral eigenvalues. The fact that supersonic disturbances may be unstable is established. An asymptotic approximation is developed for the displacement of a vortex sheet following a suddenly imposed, spatially periodic velocity.

Internal Flow

THEORETICAL RESEARCH ON EXPERIMENTAL DEVICES FOR STRAIGHT LATTICE OF AIRFOILS. S. Abe. Tōhoku U. Rep. Inst. High Speed Mech., vol. 9, 1958, pp. 1-19. 14 refs. Presentation of a method of successive approximations to calculate the characteristics of the finite profiles arranged in an experimental device, and to clarify the difference between the flow in the experimental arrangement and the ideal lattice flow, on the assumption that the flow can be treated equivalently as both two-dimensional and potential.

A comparison of the movable-wall method and the free-jet method is made by means of numerical examples, illustrating the superiority of the former. In non-lift condition, experimental values obtained by Numachi and theoretical values of the present method agree satisfactorily.

RESEARCH ON HYDROFOIL PROFILES SUITABLE FOR A STRAIGHT CASCADE OF ACCELERATED FLOW. I - THEORETICAL STUDY. II - EXPERIMENTAL STUDY. S. Abe. Tôhoku U. Rep. Inst. High Speed Mech., vol. 9, 1958, pp. 105-134. 16 refs. Statement of a theoretical method to calculate the hydrofoil profile having a given surface pressure distribution and an immovable pressure center in a given cascade condition. The successive approximation is applied on the basis of the fundamental equations of a cascade used in a previous study. For the usual blade element of axial flow turbines satisfactory results are expected by repeating the process of successive approximations two or three times. Two profiles with thickness ratios of 4% and 8% are calculated and compared with a profile of the Clark Y type, respectively.

DRUCKVERTEILUNGSMESSUNGEN UND THEORETISCHE VERGLEICHSRECHNUNGEN AN EBENEN SCHAUFELGITTERN MIT HOHEN UNTERSCHALLGESCHWINDIGKEITEN. K. H. Grewe. DFL Inst. Aero. Bericht No. 93, May 28, 1958. 53 pp. 11 refs. In German. Presentation of experimental results on pressure distribution in two-dimensional cascades at high subsonic velocities and comparison with corresponding theoretical calculations. The measurements were made at a constant Reynolds Number over the entire subsonic range on NACA 0010 and 8410 profiles, and a method was developed for evaluating compressible flow results. Results indicate that the Mach Number effect agrees with theoretical predictions for inviscid linearized flow at Mach Number values below the critical. Deviations with higher Mach Number values are discussed. It is also shown that a comparison with theory is satisfactory for small deviations of the flow below the critical value, but with strong deviation and higher subcritical Mach Number the agreement is less satisfactory.

INVESTIGATION OF DOUBLE MOTION PRINCIPLE IN AXIAL MULTISTAGE TURBOMACHINES. V. T. Yourinsky and R. G. Narayanamurthi. Indian Inst. Sci. J., Sect. B, July, 1958, pp. 121-137. Study of the characteristics of axial machinery by the method of equivalent replacements. Typical schemes are analyzed and power coefficients evaluated for comparison with axial single motion turbomachines. It is shown that the double motion adoption can intensify the force coefficient, hence the power output, and lessen the number of stages for a given enthalpy drop. However, it is shown that double motion principle can also weaken the force coefficient, if certain forms of mathematical profiles are adopted for the blading.

A TURBINE NOZZLE CASCADE FOR COOLING STUDIES. I - THE MEASUREMENT OF MEAN NUSSELT NUMBERS AT THE BLADE SURFACE. II - COMPARISON BETWEEN MEASURED AND PREDICTED MEAN NUSSELT NUMBERS AT THE BLADE SURFACE. R. I. Hodge. Gt. Brit., NGTE Memo. M. 308; M. 309, May, 1958. 25; 39 pp. 19 refs. Theoretical and experimental investigation of cooling along a turbine nozzle blade, and presentation of cascade tunnel details, instrumentation, and operating conditions. Gas to blade mean heat-transfer coefficients are determined in tests using a special blade. These experimental coefficients are related to blade Reynolds Number and to the temperature ratio between gas and blade surface. The condition of the boundary layer around a turbine nozzle blade profile in a two-dimensional cascade is described at various levels of gas flow Reynolds Number and turbulence. Mainstream turbulence is shown to have a modifying influence on the accepted transition criteria. Surface distributions of the heat transfer coefficient are calculated for the near isothermal case with laminar and turbulent boundary layers. It is shown that the combined calculated and estimated values of the profile average heat transfer rate, according to the estimated boundary layer development pattern with flow Reynolds Number, are in fair agreement with the measured values.

OPTIMUM DESIGN OF STRAIGHT-WALLED DIFFUSERS. S. J. Kline, D. E. Abbott, and R. W. Fox. Stanford U., Dept. Mech. Eng. Rep. PD-4 (AFOSR TN 58-638) [AD 162169], June, 1958. 32 pp. 37 refs. Presentation of four optimum problems in diffuser design, located in relation to overall flow regimes in terms of geometrical parameters for straight-walled units. Using an empirically derived transformation of variables between the conical and two-dimensional geometries, all available data for optimum recovery at constant ratio of wall length to throat width are correlated by a single straight line. This line lies slightly above and parallel to the line of onset of large transitory stall on the chart of overall flow regimes.

ON FULLY DEVELOPED CHANNEL FLOWS: SOME SOLUTIONS AND LIMITATIONS, AND EFFECTS OF COMPRESSIBILITY, VARIABLE PROPERTIES, AND BODY FORCES. S. H. Maslen. US, NACA TN 4319, Sept., 1958. 46 pp. Study of fully developed laminar flows indicating several limitations on such streams. The cases for liquids and gases where such motions are exact are determined and solutions are given. For more general conditions, not permitting an exact fully developed flow, limitations are set. Two cases arise depending on the size of the temperature variation across the channel. Both the forced and the free flow are solved for the case of large temperature variation. Finally, described are some circumstances under which streamwise variations of velocity occur.

ANALYTICAL AND EXPERIMENTAL INVESTIGATION OF TEMPERATURE RECOVERY FACTORS FOR FULLY DEVELOPED FLOW OF AIR IN A TUBE. R. G. Deissler, W. F. Weiland, and W. H. Lowdermilk. US, NACA TN 4376, Sept., 1958. 35 pp. 11 refs. Description of a study made for

both laminar and turbulent flow. The effect of wall temperature gradient along the tube was investigated but is important only at Mach Numbers close to unity in the turbulent case. In the laminar case the effect becomes important at much lower Mach Numbers. Recovery factors are obtained experimentally for a range of Reynolds Numbers from 630 to 30,000. The results indicate that for turbulent flow the recovery factor is approximately independent of Reynolds Number. Comparison of analytical with experimental results indicates that the effective ratio of eddy diffusivities for heat transfer to momentum transfer varies with Reynolds Number.

AIR INTAKE PROBLEMS IN SUPERSONIC PROPULSION. (NATO AGARD 11th Comb. & Propulsion Panel Meeting, Paris, Dec., 1956.) NATO AGARDograph 27. Edited by J. Fabri. Published for and on behalf of AGARD, NATO, by the Pergamon Press, New York, 1958. 97 pp. 36 refs. $5.00. Contents: Rôle de la Prise d'Air dans le Bilan Propulsif d'un Réacteur, P. Carrière. A Review of Supersonic Air Intake Problems, D. D. Wyatt. Problems Related to Matching Turbojet Engine Requirements to Inlet Performances as Function of Flight Mach Number and Angle of Attack, Antonio Ferri. Interprétation des Essais de Prises d'Air Supersoniques, L. Viaud. I - Evaluation of the role of an air intake in the jet engine balance of propulsion. Various aspects of the problem are analyzed for the case of a ram-jet with rotational symmetry at supersonic speed. The characteristic parameters are defined: flow coefficient, efficiency, and additional and external drag, as well as variation of these parameters and their order of magnitude, examined for various Mach Numbers, geometrical shapes, and conditions at the diffuser exit. II - Outline of the main parameters of supersonic air intake systems and evaluation of possible solutions based on experimental results. Includes problems associated with high pressure recoveries, definition of certain drag components, and problems of flow instability. III - Analysis limited to supersonic flight conditions, including basic criteria on entrance inlet design, three types of angle-of-attack effect, and contraction ratio design. IV - Description of some experiments on air intake models, including definitions for efficiency and aerodynamic drag, as well as test procedures and interpretation of results. A ram-type standard air intake, followed by a divergent, is proposed; the external drag is not taken into account due to its close relation to the whole body of the engine.

A THEORY OF THE CYLINDRICAL EJECTOR SUPERSONIC PROPELLING NOZZLE. H. Pearson, J. B. Holliday, and S. F. Smith. RAeS J., Oct., 1958, pp. 746-751. Development of a theory for the ejector nozzle with a cylindrical secondary shroud, based on continuity, momentum, and maximizing of the secondary flow. The results shows that the overall flow is fixed (or choked) at a condition when the outlet plane static pressure is above atmospheric, yet, the secondary flow is subsonic, as ordinarily defined. The primary flow remains supersonic. This is shown to be a general result where two streams flow through a common nozzle without mixing, whose total pressures are not the same.

THE SOLUTION OF TRICOMI'S EQUATION FOR A TRANSONIC JET. Pien Yen-Kwei. Scientia Sinica, Sept., 1958, pp. 946-963. 11 refs. Analysis of a transonic jet in which the method of approach is to reduce the problem of mixed flow into one of a purely elliptic type. The Tricomi equation in the hyperbolic region can be the same as Euler-Poisson's equation for which a general solution is available. The general solution consists of two arbitrary functions, as do most of the second-order hyperbolic equations. These two arbitrary functions can not be uniquely determined by the boundary conditions in the hyperbolic region alone; yet, there exists a functional relation between them on the sonic line. This relation serves as an additional condition for the flow in the elliptic region, and the problem is thus reduced to one of a purely elliptic type. Green's theorem for elliptic equations is then used to transform the problem into a singular integral equation.

SOME COMPRESSIBILITY AND HEAT TRANSFER CHARACTERISTICS OF THE WALL JET. M. H. Bloom and M. H. Steiger. (3rd Natl. Congr. Appl. Mech., Providence, June 11-14, 1958.) Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Paper, Dec., 1957. 32 pp. 12 refs. Investigation of compressibility and heat transfer characteristics of a jet spreading out over a plane surface in a stationary ambient atmosphere. The study covers (a) laminar flow, both planar and radial, over isothermal and nonisothermal surfaces, in regions away from the emission slot, and (b) the same jet and ambient gases, including dissociated gases in thermal equilibrium. Thermal solutions in similar form have been obtained under the special conditions that the surface temperature is equal to the ambient temperature or that the enthalpy varies monotonically from the surface value to the ambient value. Asymptotic solutions are used in the computation, a procedure for treating different jet and ambient gases is indicated, and a method for studying the turbulent case is briefly discussed.

SPRAY FORMATION AND BREAKUP, AND SPRAY COMBUSTION. A. E. Fuhs. Sundstrand Turbo AMF/TD 1199 TN 4 (AFOSR TN 58-414) [AD 158217], Feb. 5, 1958. 129 pp. 107 refs. Survey of literature in the field of liquid spray behavior. The known means for atomizing liquids, and the mechanisms for jet and sheet breakup under the various environments of non-burning media are discussed. The subsequent distributions and behavior of liquid drops in sprays are examined. Application to rocket motors of sprays formed by impinging jets is considered in detail. Spray mixing is analyzed. The empirical laws of evaporation are reviewed for single droplets and for sprays, and spray combustion is examined.

Performance

VARIATIONAL APPROACH TO THE STRATOSPHERIC CRUISE OF A TURBO-JET POWERED AIRCRAFT. Angelo Miele. ZFW, Sept., 1958, pp. 253-257. Investigation of the cruise performance of a turbojet powered aircraft traveling in the stratosphere. It is assumed that the inertia terms appearing in the equations of motion are negligible and that the zero-lift drag, the induced drag, the thrust, and the specific fuel consumption depend on the Mach Number M. By the use of indirect methods of the calculus of variations it is shown that the best operational performances are achieved by maintaining a constant Mach Number along the flight path. A generalized closed form expression is derived for the optimizing condition which includes the results of previous theories. A method for comparing the relative merit of multi-valued solutions is provided. The results of numerical examples are summarized. It is shown that a fourfold increase in the design thrust is sufficient to shift the cruising Mach Number from 0.9 to 3, and that the optimum ratio of induced drag to zero-lift drag differs considerably from the value obtained from the low-speed flight theory, ranging from 1/4 to 4 times the above value.

Wings & Airfoils

THE EFFECTS OF BLUNT LEADING EDGES ON DELTA WINGS AT MACH 5.8. Appendix I - VISCOUS INDUCED PRESSURES. Appendix II - SETTINGS IN YAW. Appendix III - COMPUTED PRESSURES. K. F. Nicholson. GALCIT Memo. 45, June 10, 1958. 72 pp. 16 refs. Measurement of pressure distributions on a series of four delta wings with subsonic and supersonic leading edges, both sharp and blunt. Schlieren studies were also made to determine top and side view shock locations. Results indicate that the effects of bluntness were small; the pressures produced by shock wave interactions with the boundary layer, and the inviscid pressures generated by the blunt leading edges, were small compared with the inviscid pressures producing lift on the basic wing. Spanwise pressure distributions show no similarity to those obtained by linearized theory.

THEORY OF CAMBERED JOUKOWSKY AIRFOILS IN SHEAR FLOW. A. Sowyrda. Cornell Aero. Lab. Rep. AI-1190-A-2 [AD 201868], Sept., 1958. 25 pp. Development of a two-dimensional airfoil theory which extends the existing theory of symmetrical Joukowsky airfoils in uniform shear flow to cambered airfoils. Some numerical results are given to show the relative effects of flow shear and airfoil camber and thickness on lift and pitching moment (there being no drag). Expressions are given from which the velocity distribution on the airfoil can be evaluated for the family of profiles and flow conditions considered.

AEROELASTICITY

AN ALTERNATIVE FORMULATION OF THE PROBLEM OF FLUTTER IN REAL FLUIDS. Wen-Hwa Chu and H. N. Abramson. Southwest Res. Inst. TR 2, Aug. 29, 1958. 17 pp. 10 refs. Analysis in which the potential theory of a harmonically oscillating thin airfoil is generalized by discarding the conventional Kutta-Joukowski condition at the trailing edge and introducing a generalized equivalent condition. The bound vorticity distribution is expressed in a form of the Birnbaum-Glauert formula and the resulting equation is solved by application of Glauert's series method. The lift and moment, which depend upon the trailing edge singularity, are found to contain two complex semiempirical parameters. The lift corresponding to these two modes of oscillation can be obtained from experiments and used to evaluate these parameters.

THE FLUTTER OF LOW ASPECT RATIO WINGS. W. P. Targoff and R. P. White, Jr. CAI-IAS Joint Meeting, Ottawa, Oct. 7, 8, 1958, Preprint 858. 36 pp. Members, $0.35; nonmembers, $0.75. USAF-supported development of a numerical matrix procedure by which the low-aspect-ratio theory formulated by Lawrence and Stone can be used to calculate the flutter characteristics of any low-aspect-ratio wing having a straight trailing edge. Correlation with experimental results indicates that, at least for 60° delta wings, the method can be used to predict adequately the flutter characteristics of low-aspect-ratio wings.

INTERPRETATION DES CALCULS DE FLUTTER POUR LES APPAREILS SUBSONIQUES. H. de l'Estoile. Docaéro, July, 1958, pp. 15-20. 10 refs. In French. Survey of various types of flutter and evaluation of assumptions introduced in the calculation. These cover aerodynamic forces, control surfaces, and sweepback. Includes methods for the interpretation of obtained results covering structural and landing gear phenomena, as well as general concepts for avoiding the occurrence of flutter.

THE USE OF MODELS IN AEROELASTIC ANALYSIS. J. A. McKillop. CAI-IAS Joint Meeting, Ottawa, Oct. 7, 8, 1958, Preprint 850. 32 pp. Members, $0.65; nonmembers, $1.00. Review of the role played by elastic models as supplements to analysis in the design process of a modern aircraft. The theory of aeroelastic model design is briefly treated and the types of models required for different applications are discussed. Model construction, instrumentation, and test techniques are presented, and some conclusions are derived regarding the role played by aeroelastic models in the design process.

AIRPLANES

Air Conditioning, Pressurization

PROBLEME DES EQUIPEMENTS DANS LES AVIONS A GRANDE VITESSE. Paul Sevin. Tech. & Sci. Aéronautiques, Dec., 1957, pp. 253-272. In French. Investigation of the thermal problem in high-speed aircraft. Two aspects of the general problem are considered: (a) development of methods for heat disposal, based on the analysis of pre-

vailing conditions, and (b) improvement in equipment to permit increased reliability during high-temperature operation. Includes presentation of data on thermal characteristics of typical structures and systems of heat disposal. The effect of weight and operation under reduced pressure are taken into account.

AVIATION & SPACE MEDICINE

DECOMPRESSION EVENTS IN BIO-SATELLITES. E. B. Konecci. ARS Semi-Annual Meeting, Los Angeles, June 8-12, 1958, Paper. 70 pp. 55 refs. Discussion on very slow to extremely rapid decompression, both accidental and intentional, in a variety of sealed, pressurized, environmental biosatellites. The physical aspects of the decompression process are reviewed. A nomogram is presented giving the relationship between cabin volume, orifice opening, and time of decompression through various pressure altitudes. The flow rates of air required to maintain 3, 6, and 9 psi pressure differentials in the cabin are measured. Theoretical computer calculations are described; they compare well with altitude chamber experimental data. Causes of slow and rapid decompressions are outlined. The subject of meteoritics is reviewed in detail. High pressure reserve supplies of oxygen and/or air carried in the satellites are covered. The use of fiberglass bottles is advocated. Safety aspects in accidental decompression are reviewed.

FUELS & LUBRICANTS

THE THERMODYNAMIC PROPERTIES OF HYDROGEN AND WATER AS POSSIBLE WORKING FLUIDS FOR NUCLEAR ROCKETS. I. Sänger-Bredt. Forschungsinst. Phys. Strahlantriebe Mitteil. 16 (AFOSR TR 58-87) [AD 162108], May, 1958. 58 pp. 22 refs. Investigation of hydrogen and water vapor as to their applicability as working fluids. Enthalpy-entropy diagrams have been computed for either gas, with regard to dissociation and ionization, over a pressure range between 10^{+1} and 10^{-5} atm, and within the temperature range between 500° and 10,000°K. The exhaust velocities possible for water or water vapor are derived and compared. The influence of the specific heats of mixtures and the mean molecular weights on the exhaust velocities attainable - before and after heating - are shown in numerical examples for hydrogen, water, and helium. Additional hydrides of light elements, such as boron III-hydride and methane, have been examined as to their applicability as working fluids. The heat transfers to the combustion chamber walls are examined by way of comparisons of hydrogen, water, and helium. The influence exerted by nonequilibrium processes on heating and expansion is discussed. Three methods of heating a working fluid have been investigated: fission reactors, electric arcs, and fusion reactors. The number of energy carriers to be supplied to the working fluid per unit time has been computed by means of the basic rocket equation, thus guarantying a definite thrust, or a definite required exhaust velocity of the rocket.

INSTRUMENTS

Flow Measuring Devices

PROPERTIES OF IMPACT PRESSURE PROBES IN FREE MOLECULE FLOW. E. L. Harris and G. N. Patterson. UTIA Rep. 52 (AFOSR TN 58-582) [AD 162102], Apr., 1958. 18 pp. Development of a theory for the mass flow through a circular tube in free molecule flow when the tube and gas are in relative motion. The gas entering the tube is assumed to have a Maxwellian distribution function, and the molecular reflection process at the wall is assumed to be diffuse. The theory is used to determine the pressure read by an impact probe in free molecule flow. Although the general expressions derived apply to any value of gas velocity and tube size, the detailed calculations for the pressure probe are difficult except for the case of low speeds and long tubes. Results of experimental studies in the UTIA low-density tunnel and a whirling arm apparatus are given. Agreement between theory and experiment is good.

MACHINE ELEMENTS

Bearings

THE INFLUENCE OF THE MOLECULAR MEAN FREE PATH ON THE PERFORMANCE OF HYDRODYNAMIC GAS LUBRICATED BEARINGS. Albert Burgdorfer. Franklin Inst. Labs. Interim Rep. I-A2049-2, June, 1958. 17 pp. ONR-supported derivation of a modified Reynolds equation for gas-lubricated hydrodynamic bearings operating under "slip flow" conditions. Closed analytical solutions are given for a Rayleigh-type step-bearing and an inclined plane slider bearing for the case of two-dimensional flow. The influence of the ratio m (molecular mean free path to a representative film thickness at a reference location) on the performance of gas lubricated bearings is analyzed. It is shown that values of $m > 0.01$ have a noticeable effect on the bearing performance factors such as load carrying capacity and the friction coefficient; they both decrease with increasing values of m.

MATERIALS

Metals & Alloys

A REVIEW OF THE LITERATURE ON THE EFFECT OF FREQUENCY ON THE FATIGUE PROPERTIES OF METALS AND ALLOYS. N. Stephenson. Gt. Brit., NGTE Memo. M.320, June, 1958. 42 pp. 68 refs. Study indicating that, at room temperature and ordinary speeds of fatigue testing (10^3 to 10^4 cycles/min.), there is little effect on fatigue or endurance limit provided the material is not in its creep range, there is no heating because of hysteresis effects, and corrosion is virtually absent. The influence of frequency is more evident under combined conditions of corrosion and fatigue. The increase of mechanical hysteresis and decrease of nominal elastic modulus with decrease in frequency at cyclic stresses which lead to failure are consistent with observations that microscopically visible plastic deformation processes associated with

fatigue failures are more developed at lower frequencies.

Metals & Alloys, Nonferrous

PREPARATION ET PROPRIETES NOUVELLES DE L'ALUMINIUM DE HAUTE PURETE. Frédéric Montariol. France, Min. de l'Air PST 344, 1958. 70 pp. 35 refs. SDIT, 2, Av. Porte-d'Issy, Paris 15, Frs. 1,580. In French. Experimental investigation of the preparation and properties of high purity aluminum. The specimens were irradiated in an atomic pile and used for the preparation of autoradiographs of the metal structure. It is shown that impurities are segregated in the interdendritic spaces of the structure; recrystallization tests indicate that the impurities are left in the final liquid stage, thus facilitating purification of the metal by zone melting. A purity of 99.999% can be attained. Such properties as ease of recrystallization and corrosion resistance are emphasized.

METEOROLOGY

Upper Air Research

RAKETNYE IZMERENIIA ELEKTRONNOI KONTSENTRATSII V IONOSFERE S POMOSHCH'IU UL'TRAKOROTKOVOLNOVOGO DISPERSIONNOGO INTERFEROMETRA. K. I. Gringauz. AN SSSR Dokl., June 21, 1958, pp. 1,234-1,237. In Russian. Results of measurements of the distribution (in relation to altitude) of electron concentration in the ionosphere obtained in USSR from high-altitude rockets between 1954-1958. An ultrashort-wave dispersion interferometer was used to measure the emission of radio waves from the rocket. The installation and the operation of rocket instruments are described, and the importance of an extraterrestrial station in terms of data accuracy and completeness is pointed out.

MISSILES

RELATIVE MOTION IN THE TERMINAL PHASE OF INTERCEPTION OF A SATELLITE OR A BALLISTIC MISSILE. Appendix - RELATION OF APPARENT GRAVITATIONAL ACCELERATION TO TIDE-GENERATING ACCELERATION AND TO DISTURBING EFFECT OF A THIRD BODY. R. A. Hord. US, NACA TN 4399, Sept., 1958. 33 pp. Study of the interception of a satellite or a ballistic missile essentially outside the earth's atmosphere with emphasis on the terminal phase of the attack vehicle's flight. For the discussion of the relative motion, a coordinate system is selected which has its origin at the target and axes always parallel to lines fixed in an inertial frame. The resulting vector equation contains, in addition to the thrust term, an apparent gravitational term. Two types of interception are discussed mathematically, and a numerical example is worked out for each type. The type of interception for which the terminal relative approach speed is small compared with the target's speed is found to be feasible. The practicability of head-on interception with mass dispersal prior to impact is more difficult to assess.

GUIDAGE PAR INERTIE DES ENGINS BALISTIQUES. J. Fitamant. Docaéro, July, 1958, pp. 35-56. 19 refs. In French. Study covering the characteristics of ballistic trajectories and the source of errors. Includes survey of the development of inertial systems; description of various units, such as gyroscopes, integrating accelerometers, and computers; evaluation of their relative methods; and presentation of illustrative examples.

ON THE BRACHISTOCHRONIC THRUST PROGRAM FOR A ROCKET POWERED MISSILE TRAVELING IN AN ISOTHERMAL MEDIUM. Angelo Miele. Jet Propulsion, Oct., 1958, pp. 675-684. 14 refs. Analysis of a burning program for a rocket-powered missile moving along a rectilinear path with the idea of minimizing the time interval necessary to reach a given point in space. The induced drag is assumed negligible with respect to the zero-lift drag; the atmosphere is regarded as isothermal. By using the indirect methods of the calculus of variations, it is shown that the totality of extremal arcs is composed of zero-thrust sub-arcs, sub-arcs flown with maximum engine output, and variable thrust sub-arcs. A numerical example shows that, assuming the initial Mach Number is zero, the optimum path includes: an initial sub-arc flown with maximum engine output, an intermediate sub-arc flown with variable thrust, and a final sub-arc flown by coasting.

NAVIGATION

INERTIAL NAVIGATION. I. C. F. O'Donnell. Franklin Inst. J., Oct., 1958, pp. 257-278. Brief survey of inertial guidance characteristics and their bearing on the suitability of inertial guidance for particular missions; the Schuler tuning of inertial platforms for error limiting is developed. A comparison between inertial guidance requirements for navigation and ballistic trajectories is made. Forms of mechanization are described and their advantages and disadvantages listed. Problems of inertial guidance, such as the choice of coordinate systems, alignment, and stabilization are outlined. Important characteristics of subsystems such as the inertial components and computers are presented. Methods of error analysis are developed and a sample system error analysis worked out. A brief description of the use of auxiliary position and velocity information in aided inertial systems is made.

POWER PLANTS

Jet & Turbine

THE DETERMINATION OF THE THERMOELASTIC STRESS DISTRIBUTION IN HOLLOW COOLED TURBINE BLADES. C. H. J. Johnson. Australia, ARL Rep. Me.87, June, 1958. 31 pp. Development of an approximate method for determining steady state thermal stress distribution, which assumes that the blade walls are thin compared with the chord, so that the temperature is constant across the wall and varies only in the direction of the surface. By representing both the internal and the external heat-transfer coefficients

as step functions of the arc length, the heat conduction is described by the solutions to a system of ordinary linear differential equations with constant coefficients.

DESIGN AND APPLICATIONS OF MACH 4 TURBINE ENGINES. M. A. Zipkin and R. E. Neitzel. CAI-IAS Joint Meeting, Ottawa, Oct. 7, 8, 1958, Preprint 859. 32 pp. Members, $0.35; nonmembers, $0.75. Study of the performance of turbine engines designed to power self-accelerating Mach 4 vehicles. Engine performance requirements are related to the mission with particular attention paid to the acceleration of the vehicle. A straight Mach 4 turbojet engine is described and the factors involved in the selection of the cycle are presented. A turbojet-ramjet engine (dual cycle) which would be based on an existing Mach 3 turbojet is also described and then compared with the straight turbojet. Applications of Mach 4 turbine engines to manned aircraft and missiles are examined and the features which make the turbine-engine powered vehicles attractive are discussed.

Ram-Jet & Pulse-Jet

RESULTATS D'ESSAIS EN SOUFFLERIE DE FOYERS DE STATOREACTEURS. André Mestre. La Recherche Aéronautique, July-Aug., 1958, pp. 11-17. In French. Description of wind-tunnel tests on ram-jet combustion chambers and presentation of experimental results. The tests were limited to a Mach Number of 1.5 and the working diameters varied from 330 to 420 mm. Measurements include the rate of fuel supply to pilot and main combustion chambers, air pressures, and combustion efficiency, based on the analysis of exhaust gases. The shock wave at the entry was studied by means of streak-visualization methods.

Rocket

ON INTERNAL BALLISTICS OF LIQUID FUEL ROCKETS. M. S. Sodha. Appl. Sci. Res., Sect. A, No. 6, 1958, pp. 421-428. Theoretical investigation of the internal ballistics of a liquid fuel rocket, taking into account the variation of droplet size distribution with time during combustion. Several simplifying assumptions are made. A steady-state solution, independent of droplet size distribution and rate of evaporation, is obtained. Assuming constant temperature throughout the combustion, the non-steady-state solution is investigated.

MISURA DEI LIMITI DI STABILITA DI ALTA FREQUENZA IN UN ENDOREATTORE A BIPROPELLENTE LIQUIDO. Luigi Crocco and Jerry Grey. (A.I.D.A. 15th Natl. Congr., Cagliari, Sept. 25-29, 1958.) L'Aerotecnica, June, 1958, pp. 135-144. In Italian. Measurement of high-frequency stability limits in a liquid bipropellant rocket. The experimental apparatus and procedure are described. The dependence of the stability limits on the nozzle configuration and the pressure in the chamber is found to be in perfect agreement with the Crocco-Cheng theory. The existence of discrete zones of instability, predicted by the theory for experimentally increasing length of the chamber, is verified.

SELECTED SCALING PROCEDURES FOR LIQUID-FUEL ROCKET ENGINES. J. W. Bjerklie, L. L. Bixson, and S. S. Penner. Sundstrand Turbo S/TD 1241 TN 6 (AFOSR TN 58-416) [AD 158219], Mar. 31, 1958. 14 pp. Theoretical study of scaling procedures with maintenance of stability for high- and low-frequency motor oscillations, and of similarity for selected Reynolds Numbers and high-frequency stability. It is concluded that the interplay of spray formation, evaporation, and chemical reactions, present interpretive and analytical problems of staggering magnitude. The requirements for similarity of some important aspects of engine combustion are shown to be mutually contradictory. A well-coordinated, long-range, experimental program, which may lead to logical procedures for optimizing the required violation of the similarity rules, is suggested.

THE EXPERIMENTAL DETERMINATION OF CHEMICAL CONVERSION TIMES IN LIQUID FUEL ROCKET ENGINES. I - THE EXPERIMENTAL DETERMINATION OF EFFECTIVE TIME DELAYS IN ROCKET ENGINES ACCORDING TO BARRERE. S. S. Penner. II - ANALYSIS OF PRESSURE DECAY AT THE TIME OF PROPELLANT SHUTOFF AND ITS RELATION TO CHEMICAL CONVERSION TIME τ, IN ROCKET THRUST CHAMBER. J. Bjerklie, E. Zwick, and L. Bixson. Sundstrand Turbo S/TD 1232 TN 5 (AFOSR TN 58-415) [AD 158218], Mar. 15, 1958. 17 pp. Presentation of experimental data linking chemical conversion time, τ, to acoustic wave times. Several methods of approach to the determination of τ form chamber pressure history after propellant shutoff are outlined. Two alternative methods of interpretation, based upon the assumptions of concentrated and distributed combustion, respectively, are discussed. The case of distributed combustion starting with a law of burning sprays, which has been shown to be in good agreement with experiments, is analyzed. The results of both analyses for distributed combustion are shown to be identical.

RESEARCH, RESEARCH FACILITIES

Wind Tunnels

DEVELOPMENT OF THE SPARK-HEATED, HYPERVELOCITY, BLOWDOWN TUNNEL - HOTSHOT. R. W. Perry and W. N. MacDermott. USAF AEDC TR 58-6 [AD 157138], June, 1958. 103 pp. 27 refs. Description of a wind tunnel capable of producing the true relative velocities of hypersonic flight. The required high stagnation enthalpies are obtained by heating a confined mass of air with a powerful electrical discharge from a large condenser bank. The resulting hot air is expanded in a Laval nozzle and produces hypersonic flow for a period of up to 50 milliseconds. Operation of the 16-in. tunnel with reservoir temperatures of 4,000°K. to 8,000°K. and reservoir pressures of 15,000 psi to 20,000 psi has been reduced to routine

practice. Also, a family of instrumentation techniques has been developed which permits conventional pressure, heat transfer, and force tests to be made in the tunnel.

STRUCTURES

Connections

THE EFFECT ON THE STATIC- AND FATIGUE PROPERTIES OF RIVETED LIGHT ALLOY LAP JOINTS OF REINFORCING THE CRITICAL SECTION WITH THIN ADHESIVE BONDED SHEETS. A. Hartman and P. de Rijk. Netherlands, NLL TN M.2047, Mar., 1958. 35 pp. Experimental study of the effect of reinforcing critical sections by local adhesive bonding of thin sheets on the static and fatigue strengths of 2-row riveted single lap joints in clad 2024-T and 7075-T aluminum alloy. Static and fatigue tests are described and the results discussed. Static strength increased almost to the tensile strength of the sheet material. Fatigue strength was noticeably increased by reinforcing with 2 strips; a further increase of the number of reinforcing strips had a negligible effect. The probability of failure of the specimens at the outer edge of the first reinforcing strip was largely increased by a high stress amplitude and by the use of 3 reinforcing strips instead of 2.

Cylinders & Shells

ZASTOSOWANIE SZEREGÓW TRYGONOMETRYCZNYCH DO OBLICZANIA ZAMKNIĘTYCH POWŁOK WALCOWYCH. Zbigniew Olesiak. Rozprawy Inżynierskie, No. 2, 1958, pp. 265-280. In Polish, with summaries in English and Russian. Application of trigonometric series to the computation of closed cylindrical shells. Solutions are given for a tube of finite length, simply supported or clamped along the edges and acted upon by any load symmetric in relation to the axis of the tube. Solutions are also given for the problem of a tube supported along three circles, and that of a very long tube supported along many circles and loaded in a periodic manner. A method is given for solving the problem of a tube of variable thickness by reducing it to a Fredholm integral equation of the second kind and determining the expansion coefficients of the deflection. Examples are included for simple loads such as a constant load or a concentrated load on the periphery.

Elasticity & Plasticity

THE INVERSION MAPPING AS APPLIED IN THE THEORY OF PLASTICITY. Wacław Olszak. Arch. Mech. Stosowanej, No. 3, 1958, pp. 417-440. 14 refs. Study considering the application of inversion transformation to the cases of the elastic-plastic and the plastic problem of a cylinder of eccentric annular cross section and a certain type of nonhomogeneity, together with the related problem of a semi-infinite plane with a circular hole. The type of mapping uses an arbitrarily chosen inversion pole, the position of which, then, does not coincide with the origin of the coordinate systems of the auxiliary (inverted) plane.

Plates

PLATES WITH DISCONTINUOUS SUPPORTS; A SEMI-INFINITE STRIP WITH DISCONTINUOUS BOUNDARY CONDITIONS. Henryk Zorski. Arch. Mech. Stosowanej, No. 3, 1958, pp. 271-313, 371-398. 15 refs. Analysis of some boundary problems with discontinuous boundary conditions considering a semiplane, a quadrant, and a semi-infinite elastic strip. The boundary conditions are assumed to be nonhomogeneous and the equilibrium equation homogeneous. These boundary conditions are understood to be two different conditions on the same segment of a straight line (part of the edge being clamped, and the remaining simply supported). The unknown functions are the deflection angle and the deflection of that part of the boundary where the angles are not given. A particular form of integral equations enables an exact solution to be obtained in a closed form.

THE BENDING OF TRANSVERSALLY NON-HOMOGENEOUS PLATES OF MODERATE THICKNESS. Marek Sokołowski. Arch. Mech. Stosowanej, No. 3, 1958, pp. 315-328. Analysis of bending in a material characterized by a one-directional variability of Young's modulus $E = E(z)$. The plate is subject to forces distributed along the vertical edges $f(x, y)$ and to a uniformly distributed load p acting normally to the surface z of the plate. The correctness of the results obtained is confirmer by substitution of the results in the basic equations of elasticity, as well as in the boundary conditions.

DRGANIA SWOBODNE I WYBOCZENIE PŁYTY TRÓJKĄTNEJ WZMOCNIONEJ ŻEBRAMI. Zbigniew Reipert. Rozprawy Inżynierskie, No. 2, 1958, pp. 231-252. In Polish, with summaries in English and Russian. Study of the free vibration and buckling of a triangular plate with ribs. The load $p(x, y)$ of the plate due to the action of the rib is expressed by a double trigonometric series. Starting from the differential equation for plates, the amplitude surface $w(x, y)$ is determined for a compressed plate loaded additionally by $p(x, y)$. The amplitude curve for the rib $v(x)$ is determined from the differential equation for the rib subjected to longitudinal compression, and the additional load $p(x)$ expressed by means of a simple trigonometric series. The determinant of a system of equations is obtained in which the unknown quantity is ω, the frequency of free vibration of the system. By setting $\omega = 0$, the critical compressive force for the rib or the critical load are found. Particular cases are examined.

THE INFINITELY WIDE CANTILEVER PLATE UNDER CONCENTRATED LOAD. J. P. O. Silberstein. Australia, ARL Rep. SM.257, May, 1958. 32 pp. Presentation of a solution by the Fourier transform method of a cantilevered strip under concentrated lateral load. By distributing the load over a small area in such a way as to keep the bearing stress within reasonable limits, physically significant bending stresses are found for all points of the plate. It is shown that for loads of high de-

gree of concentration the bending stress at the "point of application" is greater than at the root of the ledge. This feature disappears when the load becomes widely distributed. The maximum deflection of the plate is the same as that given by simple bending theory for a triangular plate of the same thickness and aspect ratio 1/3.

Sandwich Construction

THE SHEAR MODULUS OF FOIL HONEYCOMB CORES. S. Kelsey, R. A. Gellatly, and B. W. Clark. Aircraft Eng., Oct., 1958, pp. 294-302. 10 refs. Derivation of simple expressions for upper and lower limits to the shear modulus of honeycomb sandwich cores by application of the unit displacement and unit load methods in conjunction with simplifying assumptions as to the strain and stress systems in the core, respectively. The theory is given for cores built up from foil ribbons to form cells of general honeycomb form. Test methods for the experimental determination of the shear modulus are also discussed. Of these, the three-point bending test on sandwich beams is considered more satisfactory and results of such tests on steel and aluminum foil honeycombs show good agreement with theory.

Thermal Stress

A STUDY OF SEVERAL AEROTHERMOELASTIC PROBLEMS OF AIRCRAFT STRUCTURES IN HIGH-SPEED FLIGHT. J. C. Houbolt. ETH Inst. für Flugzeugstatik & Leichtbau, Mitteil. No. 5, 1958. 108 pp. 40 refs. Temperature, stress, and stiffness analysis of aircraft structures. The thermal aspects of high speed flight with both external and internal heat flow are reviewed, and a survey of the basic equations of elasticity, modified to include temperature effects, is given. Energy and equilibrium equations applicable to platelike structures of variable thickness in the large deflection range are developed, followed by a further treatment of the technique of stress function analysis, especially with regard to the treatment of boundary conditions and the analogy that may be drawn with plate bending. The solution of these problems by means of difference equations is considered in detail, and a new "summation-equation" method of solution is presented. This method is applied to a problem involving transient disturbances and yields remarkable accuracy in comparison to exact solution. A development of a flutter analysis through use of difference equations, which considers the structures and the aerodynamics in a single combined operation, is given. The problem of panel flutter and the response of panels subject to an air flow which has random pressure disturbances are treated. The reciprocal flow system is introduced for simplification purposes. The stress variation with airflow is shown to be rather similar to the deflection behavior as resonance in a simple mass oscillator is approached, or as the critical load in a column is approached.

A PHENOMENOLOGICAL THEORY FOR THE TRANSIENT CREEP OF METALS AT ELEVATED TEMPERATURES. E. Z. Stowell. US, NACA TN 4396, Sept., 1958. 31 pp. 10 refs. Modification of a previously proposed theory for the behavior of metals at elevated temperatures to yield transient creep curves by assuming that the metal consists of two phases, each with its own elasticity and viscosity. A comparison of the transient creep curves resulting from this theory with experimental data on four different metals shows that the entire family of creep curves for any one metal may be given by the theory using a single set of constants appropriate to that metal.

TRANSIENT THERMAL STRESSES PROMOTED BY THE RAPID HEATING AND COOLING OF BRITTLE CIRCULAR CYLINDERS. Appendix I, II - NATURE OF FAILURES RESULTING FROM THERMAL SHOCK TESTS. Appendix III - TYPICAL CALCULATION OF THE MAXIMUM STRESS IN A CYLINDER SUBJECTED TO THERMAL SHOCK. E. Glenny and M. G. Royston. Gt. Brit., NGTE Rep. R.226, July, 1958. 46 pp. 12 refs. Experimental investigation on the validity of the theory for calculating transient thermal stresses in brittle circular cylinders produced by rapid heating and rapid cooling, respectively. A high alumina ceramic is used as the test material and hot and cold fluidized beds as the heating and cooling media. The agreement between theory and experiment is reasonable in the light of the nonstatistical nature of the experiments and of the assumptions involved in developing and using the theory, as well as in correlating the thermal stress to failure with breaking strength.

THE RELATION OF STRENGTH TO THE THERMAL SHOCK FAILURE OF BRITTLE MATERIALS. Appendix I - THE RISK OF RUPTURE IN TENSILE AND BEND TESTS OF CIRCULAR CYLINDERS. Appendix II - THE RISK OF RUPTURE DURING THE BENDING OF A RECTANGULAR CYLINDER. Appendix III - THE RISK OF RUPTURE DUE TO THERMAL STRESSES IN A CIRCULAR CYLINDER, BIOT NUMBER LESS THAN 2. Appendix IV - THE DETERMINATION OF THE HOMOGENEITY FACTOR, m, AT ROOM TEMPERATURE. M. G. Royston. Gt. Brit., NGTE Memo. M.315, June, 1958. 22 pp. Development of a method to explain quantitatively the variation in strength of brittle materials with size and mode of stressing. By an extension of Weibull's theory a relation between bend strength and thermal fracture stress can be developed, thus permitting the design of bend strength specimens that fail under conditions analogous to those of thermal shock.

THE STATE OF STRESS IN A THIN CIRCULAR RING, DUE TO A NON-STEADY TEMPERATURE FIELD. Włodzimierz Derski. Arch. Mech. Stosowanej, No. 3, 1958, pp. 255-270. 15 refs. Analysis of stresses due to a time-variable temperature field, the temperature distribution being an axially symmetric one. The stresses are determined assuming that the edges are free and that the thermal boundary conditions are in the most general form. Assuming certain particular values of the constants involved, a number of known solutions can be obtained. The thermal boundary con-

ditions being independent of time, the passage to the limit for $t \to \infty$ enables the steady-state temperature distribution to be determined.

TEMPERATURE AND THERMAL-STRESS DISTRIBUTIONS IN SOME STRUCTURAL ELEMENTS HEATED AT A CONSTANT RATE. Appendix A - TEMPERATURE DISTRIBUTION. Appendix B - THERMAL STRESSES. W. A. Brooks, Jr. US, NACA TN 4306, Aug., 1958. 77 pp. Presentation of one-dimensional solutions for temperature and stress distributions in thick skins and structural elements such as angle, channel, T-, and H-sections when heated at a constant rate. Certain of the analytical solutions are evaluated for selected cross-sectional proportions. Results are presented in graphical form involving dimensionless temperature, stress, and time parameters, and therefore are applicable for different materials, heating rates, and absolute size of the section. The results can be used for analyzing and correlating experimental data.

STAN NAPRĘŻENIA W CIENKIEJ TARCZY KOŁOWEJ, WYWOŁANY DZIAŁANIEM NIEUSTALONEGO POLA TEMPERATURY. Włodzimierz Derski. Rozprawy Inżynierskie, No. 2, 1958, pp. 253-263. In Polish, with summaries in English and Russian. Determination of the state of stress in a thin circular plate due to nonsteady temperature field. The stresses for the steady-state temperature field are obtained by assuming that the time t tends to infinity. Results obtained coincide with those given by Mellan and Parkus. The stresses for an infinite solid circular cylinder are obtained, thermal conditions being independent of the longitudinal coordinate. The Laplace transformation is used for the temperature field and the potential of thermo-elastic displacement for the determination of the stress components.

Wings

COMBINED FLEXURE AND TORSION OF A CLASS OF THIN HEATED WINGS: A LARGE-DEFLECTION ANALYSIS. E. H. Mansfield. Gt. Brit., RAE Rep. Struc. 237, Mar., 1958. 47 pp. 11 refs. Calculation of stresses for solid or hollow wings of biconvex section with a parabolic chordwise temperature distribution. The analysis embraces the buckled, as well as the unbuckled, regimes. The nonlinear character of this large-deflection analysis stems from the fact that the middle surface forces can result from, or be modified by, changes in the spanwise curvature or in the twist per unit length. Formulas and graphs are presented which enable the distortion of a wing under given moments, torques, and thermal stresses to be determined.

THERMODYNAMICS

PROPERTIES OF GASES AT VERY HIGH TEMPERATURES. I. Admur and E. A. Mason. Phys. Fluids, Sept.-Oct., 1958, pp. 370-383. 44 refs. USAF-Navy-supported calculation of virial coefficients of the equation of state and the transport properties at very high temperatures for the rare gases and for molecular nitrogen, using known intermolecular force laws. The calculations cover the temperature range from 1,000° to 15,000°K.; only the translational degrees of freedom are taken into account, the effects of excitation, dissociation, and ionization being neglected. The treatment of mixtures is illustrated by calculations for the binary system helium-argon. The methods used offer an approach to the problem of obtaining reasonably accurate estimates of gas properties at temperatures so high that direct experiments become extremely difficult.

CRITERIA FOR THERMODYNAMIC EQUILIBRIUM IN GAS FLOW. Morton Rudin. Phys. Fluids, Sept.-Oct., 1958, pp. 384-392. 22 refs. Derivation of definite criteria for thermodynamic equilibrium in inviscid adiabatic flow of a perfect fluid and application to several cases of general interest. By the use of excitation of molecular vibration as an example, the general properties of criteria curves are interpreted. The use of these results to determine whether a flow is in thermodynamic equilibrium or not is discussed. Applications to dissociating gases, mixtures, and the phenomenon of "choking" in a Laval nozzle are given special consideration. Equations are provided for numerical forward integration along streamlines for cases when application of the criteria predicts nonequilibrium.

APPROXIMATE FORMULA FOR THE THERMAL CONDUCTIVITY OF GAS MIXTURES. E. A. Mason and S. C. Saxena. Phys. Fluids, Sept.-Oct., 1958, pp. 361-369. 42 refs. Derivation of a simple formula for the thermal conductivity of multicomponent gas mixtures from the rigorous kinetic theory by using well-defined approximations. The data needed are the thermal conductivities of the pure components at the same temperature as the mixture, the molecular weights, and either the viscosities or heat capacities of the components at the same temperature. The formula is tested by comparison with experimental results on a number of binary and ternary mixtures involving both monatomic and polyatomic nonpolar gases. Satisfactory agreement is indicated.

Combustion

RESEARCH ON STUDY OF THE TURBULENT FLAME PROPERTIES OF ELEMENTARY COMBUSTION CHAMBER FLOW PATTERNS. Appendix I - DETERMINATION OF EXTINCTION CONDITION. Appendix II - CORRECTION FACTOR FOR HOT TEST RESULTS. Appendix III - CALIBRATION OF THE KATHAROMETER FOR HOT CONDITIONS. Appendix IV - MISCELLANEOUS INVESTIGATIONS. A. B. Miller, A. Capella, and D. B. Spalding. Tiltman Langley TN 1 (AFOSR TN 58-388) [AD 154296], Feb. 24, 1958. 43 pp. Examination of the validity of tracer techniques used in predicting flame phenomena for combustion-chamber design. A detailed study of the flow behind an axially symmetrical baffle, both with and without a flame, is made. The technique used was to inject argon steadily at one point, and de-

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termine its concentration at another. The results of preliminary proving tests are given. It is shown that the differences between hot and cold flows are considerable (of the order of 5:1), but that predictions of flame blow-out, based on the cold flow measurements, agree better with the experimental blow-out data. The influence coefficients are used in conjunction with reaction rate theory to predict the extinction conditions of the baffle. A comparison of predicted values with experiment is made, and their discrepancies are explained.

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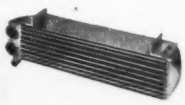

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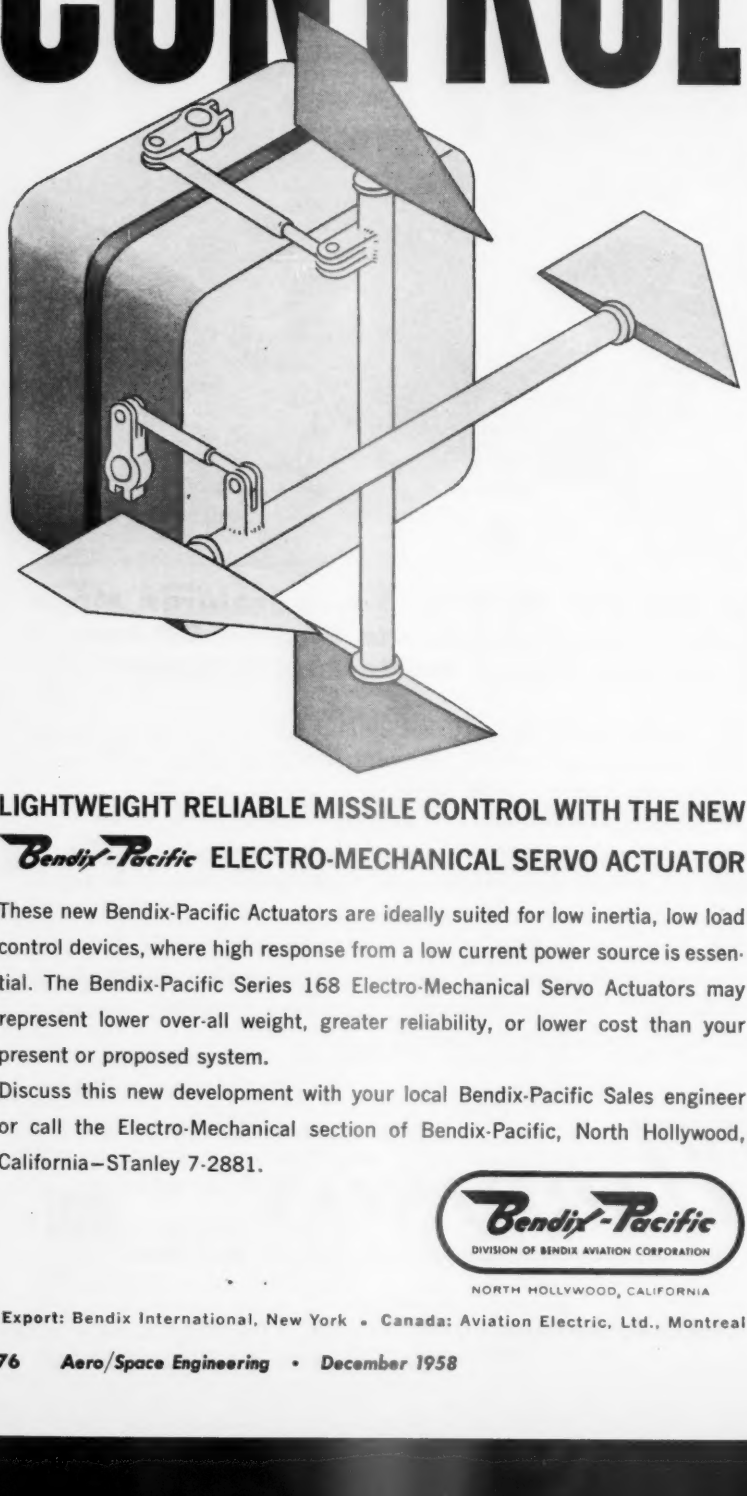

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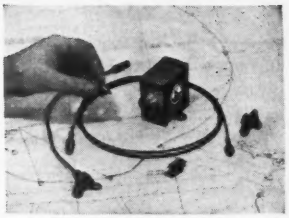

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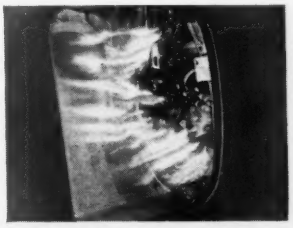

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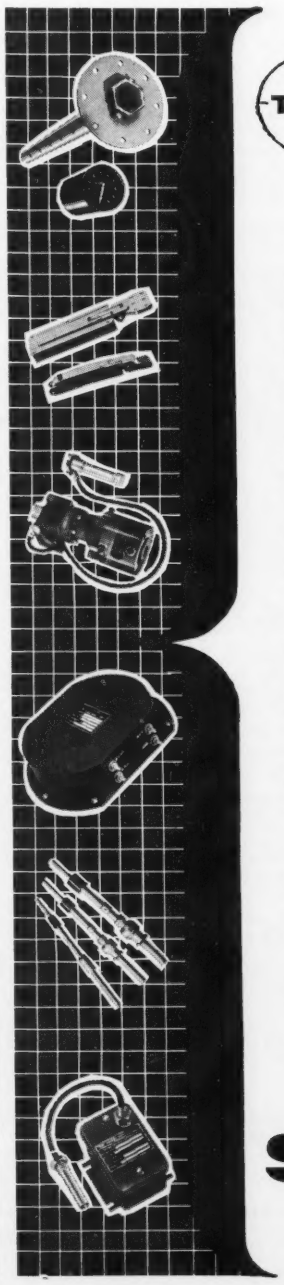

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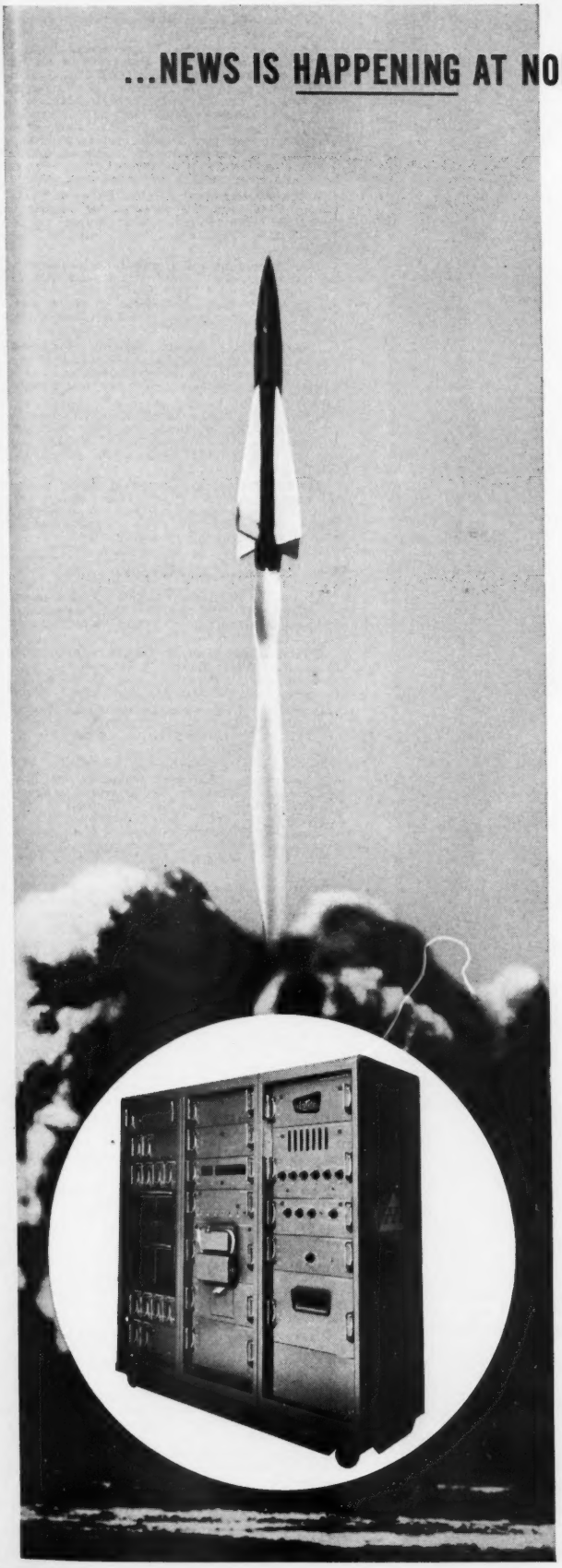

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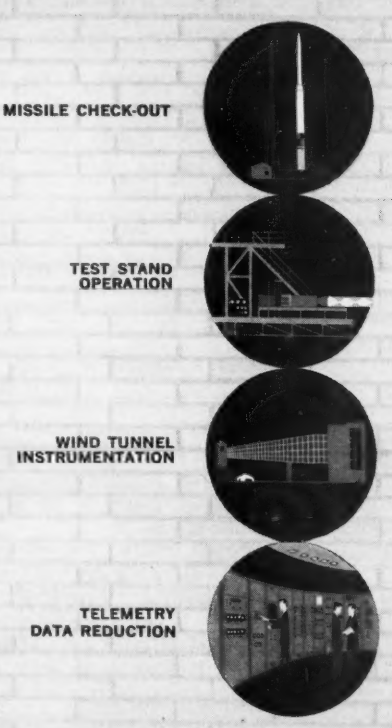

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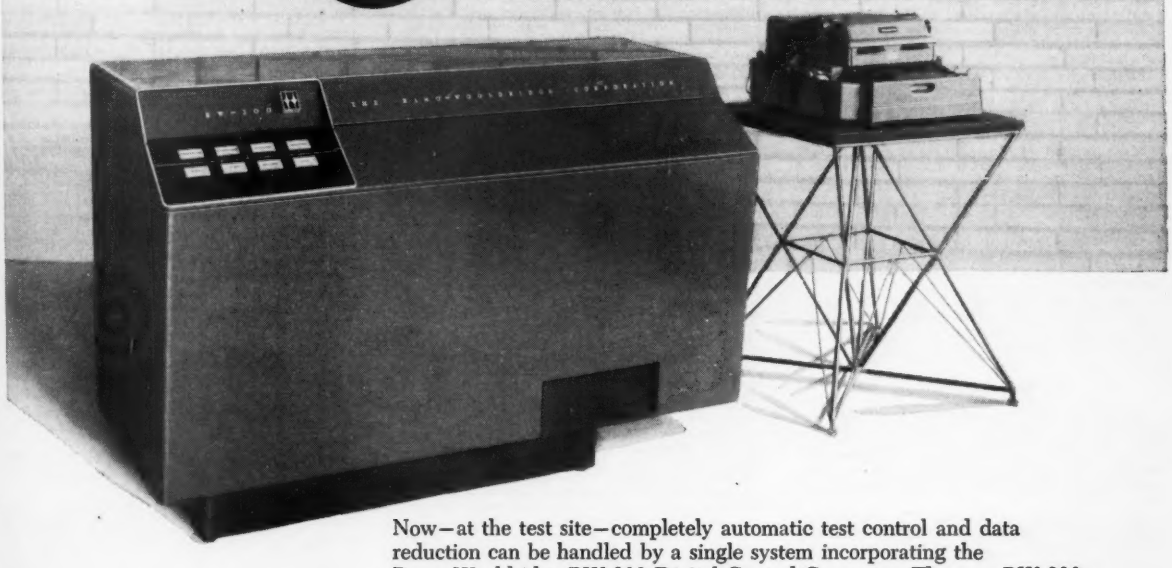

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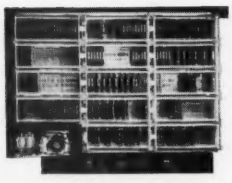

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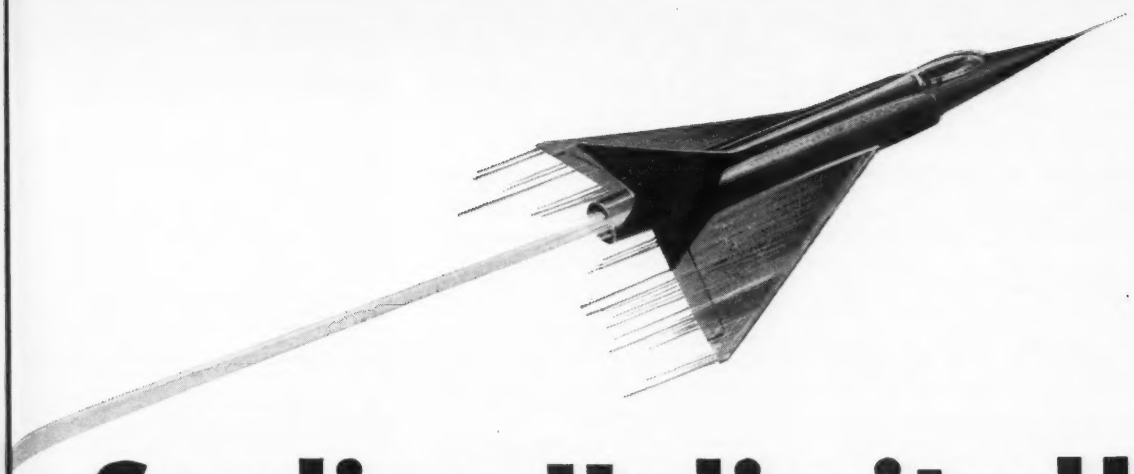

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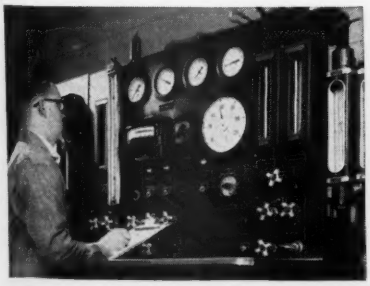

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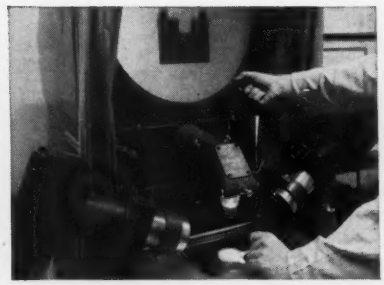

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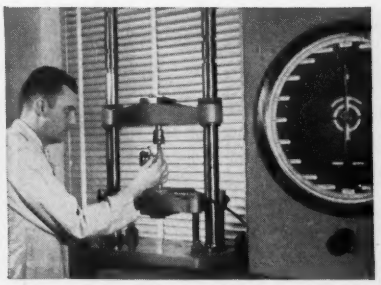

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Maurice Tucker, Aero-Thermodynamics Department Manager, right, discusses combined aero-thermodynamic re-entry body tests being conducted in Division's new "hot-shot" wind tunnel. Others are Dr. Jerome L. Fox, Assistant Department Manager, Thermodynamics, left, and Robert L. Nelson, Assistant Department Manager, Aerodynamics.

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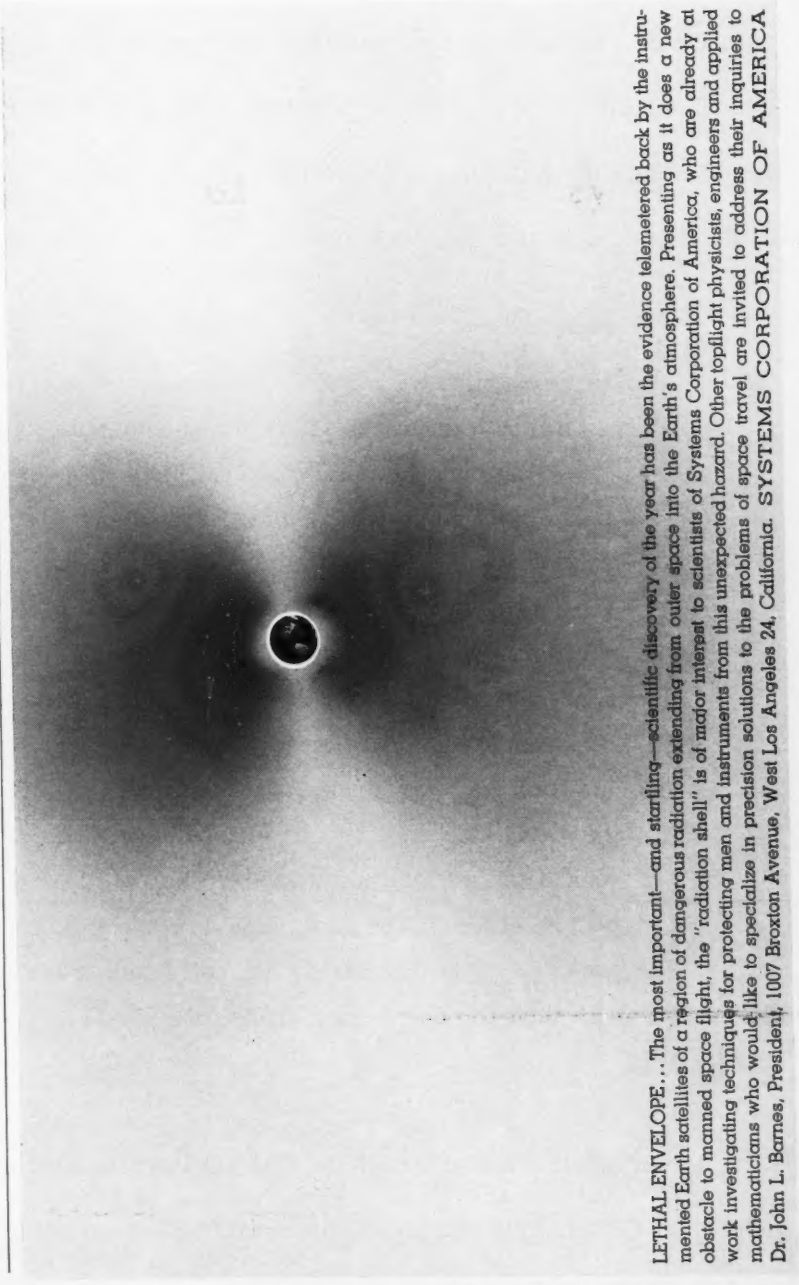
LETHAL ENVELOPE... The most important—and startling—scientific discovery of the year has been the evidence telemetered back by the instrumented Earth satellites of a region of dangerous radiation extending from outer space into the Earth's atmosphere. Presenting as it does a new obstacle to manned space flight, the "radiation shell" is of major interest to scientists of Systems Corporation of America, who are already at work investigating techniques for protecting men and instruments from this unexpected hazard. Other topflight physicists, engineers and applied mathematicians who would like to specialize in precision solutions to the problems of space travel are invited to address their inquiries to Dr. John L. Barnes, President, 1007 Broxton Avenue, West Los Angeles 24, California. SYSTEMS CORPORATION OF AMERICA

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DYNA-SOAR—the most advanced military weapon system now in development—is a pilot-controlled bomber-reconnaissance space vehicle, its mission being to circle the earth at orbital velocity, with controlled aircraft landing capabilities. It will be propelled by several stages of rocket boosters, enabling it to operate from ground level to the ionosphere at hypersonic speeds.

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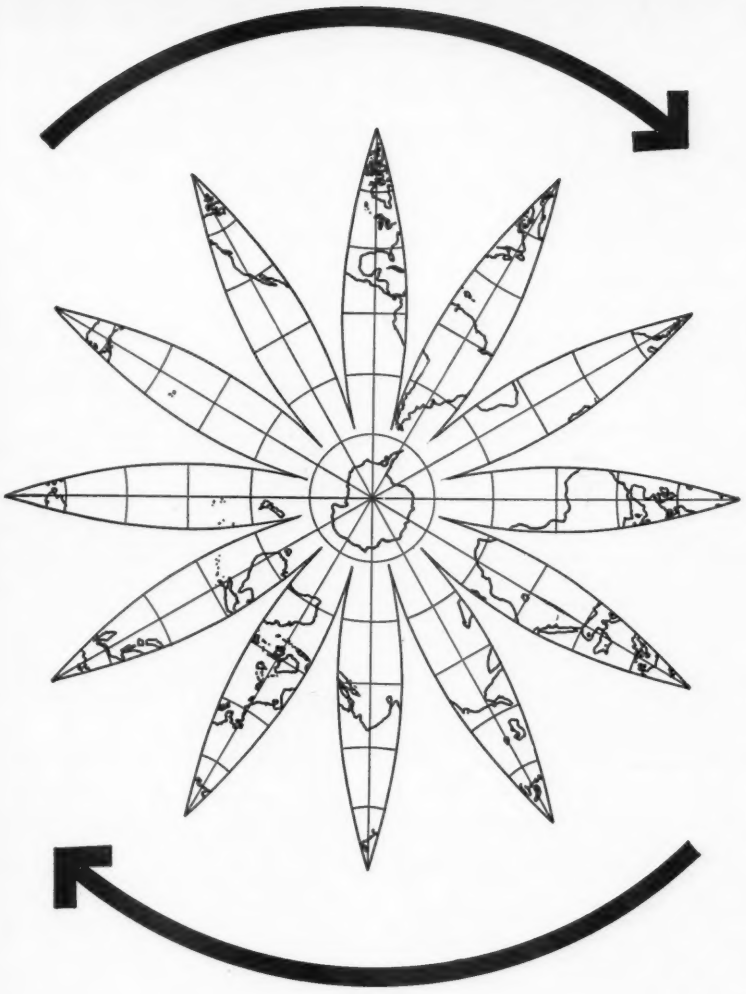

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ysis of the general theory of relativity emphasizing the relative difference between the specific and quantum theory, and the general and quantum theory, respectively.

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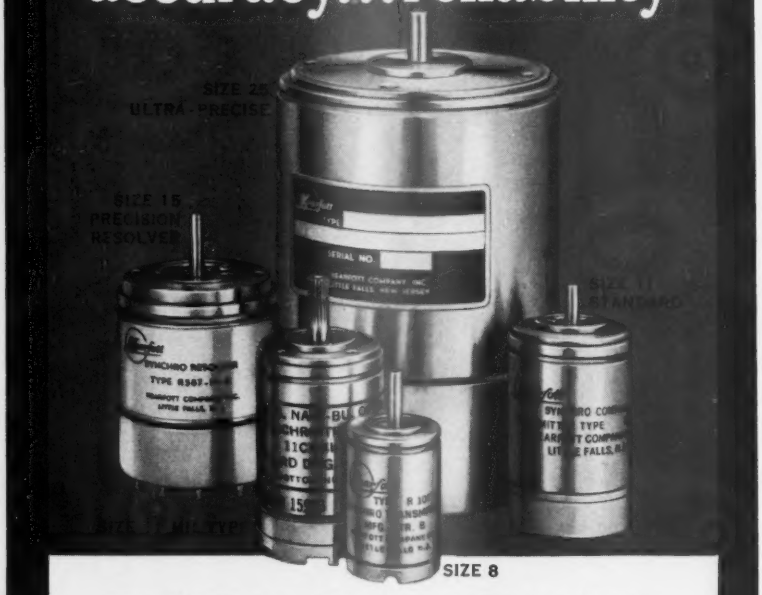

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Approximate Solutions of Transient and Two-Dimensional Flame Phenomena: Constant-Enthalpy Flames. D. B. Spalding. *Royal Soc. (London) Proc., Ser. A*, June 24, 1958, pp. 352–372. 10 refs. AFEOARDC-sponsored presentation of some approximate means of predicting transient flame phenomena. Problems discussed are those in which the volumetric reaction rate is a function of temperature alone, and in which the gas is either at rest or in uniform motion.

Heat Transfer

Approximation of the Eigenvalues for Heat Transfer in Turbulent Tube Flow. R. D. Cess. *J. Aero/Space Sci.*, Nov., 1958, pp. 723, 724.

Wärmeübergang bei der Filmkondensation reiner Dämpfe an lotrechten Wänden. H. Brauer. *Forschung Gebiete Ing., Ausg. A*, No. 4, 1958, pp. 105–117. 18 refs. In German. Survey of previous investigations and presentation of theoretical results on heat transfer laws for film condensation on vertical surfaces.

Use of Capacitor Discharges to Produce High Temperature, High Pressure Air. D. E. Bloxsom, Jr. *Jet Propulsion*, Sept., 1958, pp. 609–614. 12 refs. Description of an electrical spark gas discharge technique, using condensers, which has been applied to heat air to 9,000°K. and 40,000 psi at close to 100 per cent energy transfer efficiency.

VTOL & STOL

European Vertical and Short Take-Off Aircraft. *Interavia*, July, 1958, pp. 698, 699.

Jet Supported Vertical Take-Off Aircraft. C. T. Hewson. *Shell Av. News*, Aug., 1958, pp. 14–19. Discussion of the feasibility of building a long range, high altitude, supersonic transport VTOL aircraft. Various aspects such as engine layout, flight plan, and landing are described.

Operating from Roads and Fields: The United States Arsenal of VTOL and STOL Aircraft. *Interavia*, July, 1958, pp. 692–697.

Senkrecht in die Zukunft. Derek Harvey. *Flug-Revue*, Aug., 1958, pp. 9–11. In German. Survey of various VTOL and STOL types.

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Minimum Runway Length for an STOL Aircraft. E. M. Shoemaker. *J. Aero/Space Sci.*, Nov., 1958, pp. 720, 721. Evaluation of the optimum climb capability for the class of STOL aircraft equipped with a variable thrust vector device.

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Neue militärische und zivile Coleopter-Projekte des BTZ. *Flugwelt*, Aug., 1958, pp. 583, 584. In German. Description of the military and civil versions of the Coleopter aircraft.

Asupra Deflectării unei Vine Libere de Curent. N. N. Patraulea. *Stud. Cerc. Mec. Aplic.*, No. 1, 1958, pp. 51–62. In Rumanian, with summaries

(*Continued on page 113*)

Corporate Member News

• **Aerojet-General Corp.** has announced the appointment of William O. Wetmore as Special Assistant to William L. Rogers, Vice-President—Azusa Operations. Thomas F. Rocco has been named Corporate Field Service Base Manager at Cape Canaveral. Walter L. Tann has been appointed Special Assistant to the Vice-President and General Manager. Sidney C. Argyle has been named head of the new Optics Department, Avionics Div.

• **Aluminum Co. of America** has named William L. Fink to the newly created position of Scientific Coordinator, Alcoa Research Laboratories. He had been Chief of the labs' Physical Metallurgy Division.

• **American Airlines, Inc.,** has named Richard F. Gardiner Manager, Management Development, Personnel Department. George A. Harris has been appointed Director of Purchasing Division.

• **American Bosch Arma Corp.** has announced the appointment of Clifford A. Sharpe as Senior Vice-President.

• **Beech Aircraft Corp.** has announced the election of John A. Elliott to the firm's Board of Directors, succeeding C. C. Pearson who resigned.

• **Bendix Aviation Corp.** . . . Pacific Division reports that the AMB is evaluating its Bendix-Decca navigator system as an aid in helicopter flight. The system has reportedly been purchased by major helicopter airlines in New York, Los Angeles, and Chicago. It has been in use in Europe for some time.

• **The Bristol Aeroplane Co. (U.S.A.) Inc.** and Aerojet-General have formed a subsidiary company, Bristol-Aerojet, Ltd., and will pool their "solid rocket motor technologies," according to an announcement from Bristol. A factory will be built in England to develop, manufacture, and test solid rocket motors and propellant formulation and castings, the announcement said. Sir Reginald Verdon Smith, Bristol Chairman, will be Chairman of the new firm.

• **Douglas Aircraft Co., Inc.,** has organized a new Product Reliability Subdivision with W. L. Whittier as Product Reliability Manager. Under the new group will be the Departments of Quality Control and Materials-Process Engineering and a new Manufacturing Reliability Assurance Department.

• **Eastern Air Lines, Inc.,** reports that it has ordered a "7070" electronic data processing system from IBM for installation at Miami.

• **Fairchild Engine and Airplane Corp.** . . . Guided Missiles Division has named Hamilton O. Hauck Director, Technical Department. He had been Director, Guided Missiles Division, BuAer. The firm also announced the formation of a new Applied Science Division, headed by Warren R. Smith, General Manager, for long-range planning and engineering service for the parent corporation.

• **General Dynamics Corp.** . . . Convair Division reports that five 880 airliners are in major assembly fixtures or moving down the production line in San Diego. The division also has announced activation of Datafax Instruments, a new program to design, develop, and produce a line of specialized mechanical and electrical instruments and instrument systems. Egon E. Muehlner, formerly a design specialist for both Convair-San Diego and Convair-Astronautics, has been named Datafax Project Engineer.

• **General Electric Co.** reports that its CJ-805-3 commercial jet engine has received its CAA final-type certificate. The firm's Everett, Mass., plant, formerly operated by the Small Aircraft Engine Department, is now under the control of the Production Engine Department. The Air Force Sales Unit in the Heavy Military Electronics Department has set up an Advanced Development Sales organization, with C. W. Cowing as Manager.

• **ITT Laboratories, a Division of International Telephone and Telegraph Corp.,** has announced the appointments of Donald F. Wentzler as Director, Planning and Organization, and Edward J. Felesina as Director of Public Relations and Advertising.

• **Johns-Manville Corp.** has proposed a merger with L. O. F. Glass Fibers Co. on the basis of one share of its common stock for $2^1/_2$ shares of the glass company's common stock.

• **Kollsman Instrument Corp.** has announced the promotions of Wesley C. Bonn to Assistant to the President in charge of Customer Relations and Advertising, and Henry N. Droge to General Sales Manager.

• **Lockheed Aircraft Corp.** . . . Georgia Division has announced the appointment of Robert D. Roche as Operations Research Division Manager.

• **Marquardt Aircraft Co.** has announced acquisition of Associated Missile Products Co., an AMF division. It will be operated as the Marquardt Pomona Division. J. M. Norris has been named Factory Manager of the firm's Ogden, Utah, ram-jet manufacturing facility.

• **North American Aviation, Inc.,** has announced the formation of Aero-Space Laboratories in its Missile Division. The labs are headed by the division's Chief Scientist, E. R. van Driest (M), and will be responsible for basic and creative research activities. Assisting Dr. van Driest in organizing the labs are Harold Bell (M), former Chief of Technical Sciences, and Manuel Sanz, former Chief Laboratory Scientist. One of the first steps to be taken will be the formation of a satellite information center.

• **Pesco Products Division, Borg-Warner Corp.,** has established a new branch sales office in New York with Joseph A. Wilson as Manager.

• **The Ramo-Wooldridge Corp.** . . . Space Technology Laboratories, Inc., has four new members on its Board of Directors: Louis G. Dunn, President and General Manager; Ruben F. Mettler, Vice-President and Assistant General Manager; James T. Brown, Vice-President, Mellon National Bank; and Samuel E. Gates, attorney with Debevoise, Plimpton and McLean. . . . The Thompson-Ramo-Wooldridge Products Co. has named Thomas M. Stout Manager, Process Applications Department, Engineering Division.

• **Simmonds Aerocessories, Inc.,** has announced the election of Geoffrey R. Simmonds as President and a Director.

• **Socony Mobil Oil Co., Inc.,** reports it will use a new high-pressure system at Lisbon, Beirut, and Dakar for refueling jets at the rate of 1,200 g.p.m.

• **Thiokol Chemical Corp.** has announced the appointment of Charles E. Hunter as Special Assistant to the President. He formerly was General Manager, Hunter Bristol Corp.

• **United Air Lines, Inc.,** reports construction of a building to house jet-engine test facilities at the company's San Francisco Maintenance Base. The building will have two test cells, a control room, and other facilities in an area of 9,560 sq.ft. The firm also says it has put into operation the world's first jet aircraft simulator for airline use at its Denver training center.

• **United Aircraft Corp.** has named Leete P. Doty Assistant General Manager, Sikorsky Aircraft Division. He had been a senior production executive at Pratt & Whitney Aircraft Division. This division reports that the Air Force has extended J-57 overhaul time from 1,000 to 1,400 hours on the B-52 and from 800 to 1,400 hours on the KC-135.

• **Vard, Inc.,** announced that it had received six of 14 machine tools that are being added to its Pasadena facilities as part of the firm's modernization program. The program also includes the building of special facilities for on-site test programs and the partial rearrangement of plant layout to improve production efficiency.

• **Vertol Aircraft Corp.** has elected the following vice-presidents: James N. Davis, Hamilton W. Lord, and Vergil J. Wiltse. Mr. Davis will handle Government operations; Mr. Lord, also Treasurer, handles finances; and Mr. Wiltse, industrial relations.

• **Vickers, Incorporated** has named Charles D. Scribner to fill the newly created post of Vice-President for Personnel. The firm also announced that its 8th Annual Hydraulics Conference was held at Detroit, November 12–14.

• **Vitro Corp. of America** and Koppers Co., Inc., have announced the signing of a "joint venture" agreement to enable Vitro Laboratories and Koppers' Metal Products Division to undertake all phases of weapon systems work from research and development through large-scale manufacture.

• **Westinghouse Electric Corp.** has demonstrated an electric power station designed for use on the moon. This was done under the auspices of the firm's new Astronautics Institute headed by Peter Castruccio of the Air Arm Division. Theory, design, and construction of the model were performed by scientists of the Applied Research Laboratory, Electronic Tube Division.

Dayton-Cincinnati Section

707 Jet Transport Derives From Bomber

Maynard L. Pennell, Chief Engineer, Transport Division, Boeing Airplane Co., presented a comprehensive review of **"The Boeing Family of Jet Transports"** on September 25.

Mr. Pennell, original project engineer on the 707 jet transport, traced development of the aircraft from the B-47 bomber, through the B-52 and KC-135 tanker.

His presentation included movies of various military aircraft flight tests and colored slides showing the performance of several versions of the 707.

In a discussion period following his talk, Mr. Pennell answered many questions about the 707's commercial operation.

DAVID F. JAMISON
Secretary

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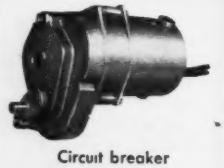

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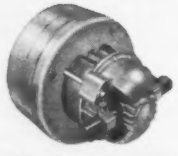

Turbine for canister-type vacuum cleaner.

Los Angeles Section

Three Meetings Held in September

The process by which roughness causes **"Boundary-Layer Transition"** was explained by **A. M. O. Smith** at the September 23 specialist meeting. His talk was based upon a work undertaken with D. W. Clutter to determine the smallest height of roughness capable of affecting transition.

Once the flow model was understood, extension of the low-speed results to the supersonic problem became straightforward. The effects of various types of roughness were also discussed.

▶ New officers installed at the September 18 meeting were Chairman, M. J. Abzug; Vice-Chairman, R. G. Fuller; Secretary H. R. Saffell; and Treasurer, D. A Justice.

Brigadier General E. F. Easterbrook, Director, Army Aviation, described the mission of **"Army Aviation"** and outlined the Army's role in warfare. He made a strong plea for the use of mission rather than aircraft weight as the criterion for limiting Army aviation.

▶ **"Test Facilities"** for the study of aerodynamic and thermodynamic problems associated with hypersonic flight through air were reviewed by **Dr. Toshi Kubota at** the September 9 meeting. He classified facilities for hypersonic aerodynamics according to types of driving mechanism, methods of heating the working fluid, and duration of flow and compared their characteristics.

H. R. SAFFELL, *Secretary*

Texas Section

Management Team Needs Technical People

C. J. McCarthy, Board Chairman, Chance Vought Aircraft, Incorporated, spoke on **"Aviation Economics"** at the September 19 dinner meeting.

Mr. McCarthy pointed out that on both a national and a company scale it is impossible to use all of the ideas suggested by engineers and scientists because of the excessive costs involved. He stressed the importance of integrating technical people into decision-making areas of the company so that promising ideas may be retained.

Mr. McCarthy said that profits of the aviation industry have been, and are, consistently below those of other industries. He said that military contracts were becoming more difficult and restrictive and expressed the hope that the controversial excess profits renegotiation act would not be extended beyond the middle of 1959.

VERNON A. LEE, *Secretary*

Tulsa Section

Heating Causes and Effects Discussed

Frank J. Lyon, Senior Engineer in the Aero-Thermo Research Group at North American's Columbus Division, discussed **"Aerodynamic Heating"** on September 9.

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Through a description of the physical phenomena occurring on the surface of moving bodies, Mr. Lyon explained the causes and effects of aerodynamic heating. Transient and equilibrium temperatures were illustrated, and methods for maintaining these temperatures below desired limits were outlined.

ALLAN M. MCCASKILL
Recording Secretary

Washington Section

NASA Planning Given Early to IAS Members

The first public announcement of the NASA's space plans came in a talk entitled **"A General Review of the NASA Space Program"** by **Edgar M. Cortright** before this Section on September 9. Mr. Cortright is Chief, Plasma Physics Branch, Lewis Research Center.

He was introduced by Abe Silverstein, NASA Director of Space Flight Development, who said extension of basic knowledge of the universe will be NASA's most important goal. Dr. Silverstein also said the gains that will be made will more than compensate for the cost of the program.

Mr. Cortright described NASA's initial steps as a structure on which to hang the integral pieces necessary to build a solid, complete program. He said NASA will take over and extend the IGY Explorer and Vanguard projects. Areas under study include satellites of 100 to 120 lbs., 200-lb. satellites with stabilized platforms, and 300-lb. satellites with spin stabilization. These devices will be used to obtain data on the amount of hydrogen and cosmic dust in space and for astronomic observations.

The program also calls for various space probes with plans for three Thor-Able and two Juno II lunar shots. Early manned space flights will probably use a relatively simple capsule, existing ICBM hardware, and known techniques developed from ballistic and re-entry testing programs.

A vigorous program creating advanced components is needed to continue the space program, he said. New propulsion units must be developed including large boosters for initial launching and small rockets for maneuvering in space. Nuclear fission units are in the first model design stage. A large booster of one million or 1.5 million lbs. thrust is needed, but for this type of unit conventional fuels are inadequate. But with promising high-energy fuels, up to fifteen times more payload will be possible on a moon landing flight.

Mr. Cortright discussed several types of auxiliary power systems that might meet auxiliary power requirements. These included guidance systems for initial, mid-course, and terminal phases of flight and radio communications systems. He said radio messages may be sent from Mars at reasonable levels of power by using slow transmission and coding techniques.

He also pointed out the need for special vehicles to test related hardware from the fields of meteorology, biology, astronomy, and vehicle control.

QUENTIN J. GOSS, *Secretary*

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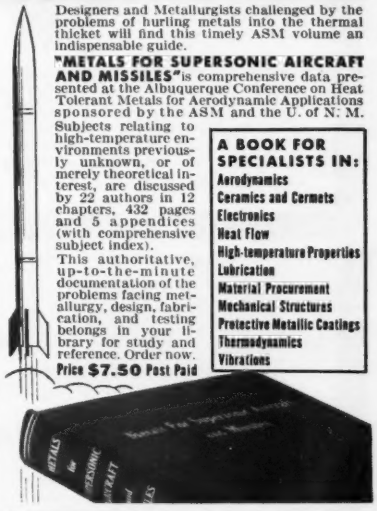

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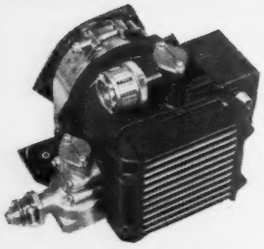

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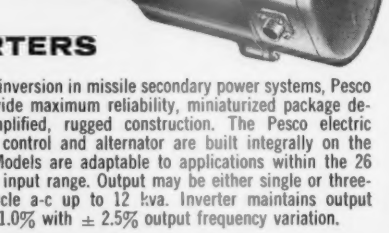

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ACOUSTICS

Physical Acoustics and the Properties of Solids. Warren P. Mason. Princeton, N.J., D. Van Nostrand Co., Inc., 1958. 402 pp., illus., diagrs., tables. $9.00.

This introduction to the uses of wave transmission in solids provides both engineering applications and analytical uses. Background information is contained in chapters on wave propagation in solids, in transducer materials, and in phenomenological models. One chapter describes various methods that have been used in measuring the properties of solids and polymer liquids which are the equivalent of glassy solids at high frequencies. A chapter is devoted to low-amplitude devices and another to high-amplitude devices. In the field of analysis, subjects covered are the effects of thermal conductivity, sound scattering, effect of domain wall motion and domain rotation on the acoustic properties of ferromagnetic and ferroelectric materials, interstitial and substitutional atom relaxations, dislocation models for low- and high-amplitude strains, internal friction in quartz, fused silica and glasses, and crystal lattice interactions with electrons and phonons. It is emphasized that the fields of devices and analysis are closely coupled since improvements in devices can come only from an analysis of the fundamental transmission properties of solids.

Because of the wide diversity in the possible applications of these devices and in the professional backgrounds of their potential users, the author, who is Head, Mechanics Research, Bell Telephone Laboratories, has presented the underlying physics as simply as possible and kept mathematics to a minimum.

AERODYNAMICS

Aerodynamics of Supersonic Flight; An Introduction. Alan Pope. 2nd Ed. New York, Pitman Publishing Corp., 1958. 243 pp., illus., diagrs., tables. $6.00.

This second edition has been lengthened to include the complete aerodynamic theory and design of a simple supersonic wind tunnel and a brief discussion of supersonic performance from the practical side. Along the lines of student utility, simplified isentropic and normal shock tables have been added. The author is head, Aerodynamics Department, Sandia Corp.

Contents (1) Fundamental Relations. (2) Flow in a Duct. (3) Two-Dimensional Flow. (4) The Oblique Shock. (5) Approximate Theories. (6) Supersonic Wind Tunnels. (7) Three-Dimensional Flow. (8) Performance Calculations. Answers to Problems. Appendix: Standard Atmosphere. Index.

AIR TRANSPORTATION

The Economic Implications of the Introduction into Service of Long-Range Jet Aircraft. International Civil Aviation Organization. Montreal, ICAO, 1958. 66 pp., diagrs., tables. $1.25.

This study in implementation of ICAO Resolution A10-34 attempts to assess what appear to be the main economic implications of the introduction into service of the long-range turbojet airliners now on order in considerable quantity. First, the changing nature of the world's scheduled airline fleets is described—particularly the changeover to turbine power—as well as the general increase in size, speed, capacity, and price of the aircraft due to come into use in the next few years. Next, the differential characteristics of the larger jets are dealt with, and it will be seen that in a number of important respects—particularly in regard to weight, capacity, and price—they are outside the normal trends within which the other new aircraft on order fall.

Attention is then given to some general economic factors, such as the effects of recessions on the air transport industry, forecasts of supply of and demand for air transport productive capacity, and the stage and traffic patterns of international air services; and finally, the economic implications of the new aircraft for operators, users, and governments are examined.

I Flew Them Home; A Pilot's Story of the Yemenite Airlift. Edward Trueblood Martin. (Herzl Institute Pamphlet No. 9.) New York, The Herzl Press, 1958. 64 pp., 1 map. $0.50.

The author's personal account of his part in the airlift which successfully transported thousands of Yemenite Jews from Aden to Israel at the height of the Israeli-Arab war.

COMPUTERS

Basics of Digital Computers. John S. Murphy. 3 vols. New York, John F. Rider Publishers, Inc., 1958. *Vol. 1*, 116 pp., diagrs.; *Vol. 2*, 133 pp., diagrs.; *Vol. 3*, 136 pp., diagrs. Each volume, $2.50.

Material is included in these volumes on the basis of its being common to or representative of digital computers in general. The books, therefore, fit naturally into the "basic" electronic series. The subject matter has been distilled into easy-to-learn "picture book" form and is presented especially to serve as an aid to persons entering the computer or allied fields.

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Vol. 3. Computer Memory. Magnetic Recording. Reading and Writing. Timing Pulses. Storage Registers. Computer Time. Time Standards. Control Units. Instructions. Subdivision. Control Circuits. Input-Output. Printers. Input-Output Units.

Electronic Digital Computers; Their Use in Science and Engineering. Franz L. Alt. (*Applied Mathematics and Mechanics, Vol. 4.*) New York, Academic Press, Inc., 1958. 336 pp., diagrs. $10.

Intended to serve as an introduction to the field, this volume is aimed particularly at physicists, chemists, engineers, and others in occupations in which machine computation finds frequent application. They, as a rule, will not do their own programing but will obtain help from professional programers; this book is, therefore, an attempt to supply as much information as they need in order to talk intelligently to the computer specialists with whom they deal. Consequently, the description of the machines does not presuppose any knowledge of engineering and deals mostly with the functioning, rather than the design, of machines, although some of the underlying physical principles are mentioned because of their general interest.

Representative samples of computer applications are given, including at least two or three problems from each of the major fields in which these machines have been used, and the machine characteristics required for their solution are indicated, as are the criteria by which the originator of a problem may judge the suitability of a particular machine installation for his problem.

Transactions of the Short Course and Conference on Automation and Computers, June 2–4, 1958. 2 vols. Presented as Part of the College of Engineering's Contribution to The University of Texas' 75th Year Anniversary Observance; Sponsored Jointly by the Society of Petroleum Engineers. Austin, Tex., The University of Texas, 1958. *Vol. 1*, 210 pp., illus., diagrs., tables; *Vol. 2*, 113 pp., illus., diagrs.

Contents: Vol. 1. Programming a Digital Process Control Computer for System Reliability, W. S. Aiken. The Digital Computation Mission in the Missile Development Field, C. L. Bradshaw. The Digital Computer in Engineering Education, Dr. Lymon C. Reese. Flow and Storage of Material, Dr. H. O. Neukomm. From Problem to Solution, Dr. A. B. Farnell. Automation in Missile Systems, Otto Hirschler. A Flight Data System, C. N. Batsel, Jr., R. E. Montijo, Jr., and E. J. Smuckler. Automatic Flight Control, Louis B. Wadel. The Role of the Small Computer in Industrial Research, Dr. H. Norman Abramson. Application of Computers To Well Logging Problems, Dr. James Moran. Financial Justification for Automation, W. L. Miron. Introduction to the Steel Rolling Process, K. R. Thompson. Electro-Acoustical Analog for Pulsation Suppression and Control in Gas Compression Stations, Glenn Damewood and Water Nimitz. Application of an Automatic Data Handling System to an Aircraft Company's Testing Division, Dr. C. E. Pettingall. Frontiers of Computer Application, Dr. Ascher Opler. Digital Computer Programming—A Must for the Modern Designer, Dr. Marshall Middleton.

Vol. 2. A Review of Automation, Dr. Eugene M. Grabbe. A Perspective View of Analog Computers, R. B. Blanning. Logical Aspects and Sidelights in Computation, Dr. Robert E. Greenwood. The Use of a Computer as a Research Tool, Robert W. DeSio. Digital Computer Functions in Numerical Control, George H. McDaniel. Use of Computers in Process Research, E. A. McCracken. Analog Computers—Wheelhorses of Automation, D. J. Simmons. What is Automatic Programming?, Dr. V. M. Wolontis. List of Participants. Complete Program. Committee.

DICTIONARIES

Chambers's Technical Dictionary. 3rd Rev. Ed. with Supplement. Edited by C. F. Tweney and L. E. C. Hughes. New York, The Macmillan Co., 1958. 1,028 pp. $7.50.

The new edition of this reference work contains 55,000 entries drawn from more than 100 branches of scientific and industrial activity. It includes a 74-page supplement with nearly 5,000 definitions of important new terms covering the latest advances in science and technology. Among the additions are aeronautical terms dealing with supersonic flight, guided missiles, and the latest aeroengines; definitions of electronic terms used in connection with computers and automation; and definitions of the latest words in astronomy and in nuclear physics. The most recent discoveries regarding chemical elements are included in the tables at the end of the book.

Dictionary of Physics. Compiled and Edited by H. J. Gray. London; New York, Longmans, Green and Co., 1958. 544 pp., diagrs., tables. $16.50.

This moderate-sized but comprehensive British dictionary of useful information on physics and its applications is intended for professional physicists, scientists and engineers working in cognate fields, students, teachers, and the general public. In addition to the traditional and newer subdivisions of physics (including quantum mechanics, atomic and nuclear physics), the dictionary contains many entries in applied physics—touching on such subjects as electrical technology, telecommunications, applied acoustics, technical optics, and applied thermodynamics. There are also entries in closely related fields such as astronomy, mathematics, and electrotechnology, plus articles on the elements and their isotopes and biographical sketches.

Arrangement of the material is alphabetical, with numerous cross references and diagrams. Wherever appropriate, the entries lead on to further reading, either by cross reference to one of the longer articles or by the use of specialized books or original research papers which are quoted at the end of the article.

Russian-English Glossary of Guided Missile, Rocket, and Satellite Terms. Compiled by Alexander Rosenberg. Washington, Card Division, U.S. Library of Congress, 1958. 352 pp. $2.50.

The more than 4,000 alphabetical entries in this glossary were taken from monographs and periodicals published in the Soviet Union during the period 1955–1958. Accompanying the more obvious missile and satellite terms are numerous others taken from the fields of astronomy, astrophysics, electronics, and aeronautics; also included are the names of many governmental and quasi-official agencies operating in Russia and the United States. The English equivalents of the terms (checked against authoritative American sources) are based primarily on Soviet translations of American and British publications.

DOCUMENTATION

Centralized Information Services: Opportunities and Problems. Allen Kent and James W. Perry. Cleveland, The Press of Western Reserve University, 1958; Distributed by Interscience Publishers, New York. 156 pp., diagrs. $5.00.

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FLUID MECHANICS

Mathematical Theory of Compressible Fluid Flow. Richard von Mises; completed by Hilda Geiringer and G. S. S. Ludford. (*Applied Mathematics and Mechanics, Vol. 3; Edited by F. N. Frenkiel.*) New York, Academic Press, Inc., 1958. 514 pp., diagrs. $15.

When Richard von Mises died in 1953, he had completed only the first three chapters of what was intended to be a comprehensive work on compressible flow. To help form a complete, advanced text for graduate students and research workers, these chapters have been augmented with material on the theory of steady plane flow. The work embodies von Mises' ideas on a central branch of fluid mechanics, with emphasis on fundamentals, both conceptual and mathematical.

The novel concept of a specifying equation clarifies the role of thermodynamics in the mechanics of compressible fluids; the general theory of characteristics is treated in a complete and simple manner, with detailed applications; and the theory of shocks as asymptotic phenomena is set within the context of rational mechanics. Chapters IV and V, written by H. Geiringer and G. S. S. Ludford with the author's papers and lecture notes as guide, are devoted to a discussion of shock theory, a study of transonic flow, and a presentation of the hodograph method which includes a discussion and comparison of the modern integration theories.

Independent of the text are more than 40 pages of bibliographical and historical notes and addenda.

HELICOPTERS

Proceedings of the Third Annual Western Forum, American Helicopter Society, Held in Dallas, Texas, October 7-9, 1956. New York, American Helicopter Society, Inc., 1956. 69 pp., illus., diagrs. Member price: $3.00; nonmember price: $5.50. Separate papers available at 25 cents each.

Contents: (1) Application of Boundary Layer Control to Helicopter Rotor Blades, Sanford Hinton. (2) Helicopter Longitudinal Stability and Control in Forward Flight with Control Feed Back, Kenneth G. Wernicke. (3) Development of a Retractable Rotor, Tadeusz Tarczynski. (4) The Advantages of the Ducted Propeller in VTOL Aircraft Design, Norman E. Nelson. (5) High Altitude Operation of Helicopters, Paul E. Young. (6) User Testing of Helicopters by the Army, W. H. Byrd. (7) Army Helicopters in Central and South America, Thomas J. Sabiston.

Proceedings of the Fourth Annual Western Forum, American Helicopter Society, Held at St. Louis, Mo., October 21-22, 1957. New York, American Helicopter Society, Inc., 1957. 159 pp., illus., diagrs. Member price: $2.00; nonmember price: $4.00. Separate papers available at 25 cents each.

Contents: (1) Raydist—A Solution to the Helicopter Navigation Problem, Charles E. Hastings and Joseph T. Bradbury. (2) Helicopter Navigation by Loran-C, Winslow Palmer. (3) Some Aspects of the Flying Crane, F. L. Doblhoff. (4) Trends for Optimum Flying Crane Design, J. A. DeTore. (5) The Hot Cycle Pressure Jet Flying Crane, H. Hirsch and R. Sullivan. (6) The Bendix-Decca Navigation System Applied to Helicopter Operations, J. H. Overholser (abstract). (7) A Note on the Crane Helicopter, Edward F. Katzenberger (abstract). (8) Influence of Engineering Decisions on Sales and Financial Management, Paul W. Holt. (9) Influence of Engineering Decisions on Manufacturing, Maurice L. Bernsen. (10) Influence of Engineering Decisions on Spare Parts and Maintenance Management, Carl W. Diehl. (11) Integration of Engineering Decisions Through Electronic Data Processing, James E. Sutherland.

MAGNETOHYDRODYNAMICS

The Plasma in a Magnetic Field; A Symposium on Magnetohydrodynamics. Edited by Rolf K. M. Landshoff. Stanford, Calif., Stanford University Press, 1958. 130 pp., illus., diagrs. $4.50.

The present volume is the second to grow out of a Lockheed-sponsored symposium on magnetohydrodynamics held at the Palo Alto laboratory of the Missile Systems Division on December 16, 1957. The general remarks of the Preface to the first volume (*Magnetohydrodynamics; A Symposium*, reviewed in AERONAUTICAL ENGINEERING REVIEW, *November, 1957*) concerning the intent of both the symposium and the book still apply. The changed title reflects the much wider interest in phenomena involving plasmas rather than liquid metals.

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Contents: I. Kinetic Theory: Adiabatic Invariants in the Motions of Charged Particles, S. Chandrasekhar; Hydromagnetic Basis for Treatment of Plasmas, M. Rosenbluth. *II. Confinement and Instabilities of a Plasma:* Mechanism of Ion Acceleration by Dynamic Pinch Instabilities, S. Colgate; Experimental Studies of the Pinch Effect, H. J. Karr; Confinement of a Plasma Column by Radiation Pressure, E. S. Weibel; Plasma Instability in the Interplanetary Magnetic Field, E. N. Parker. *III. High-Speed Fluid Dynamics:* Experiments Using a Hydromagnetic Shock Tube, V. H. Blackman and B. Niblett; Velocity Measurements in Magnetically Driven Shock Tubes, S. W. Kash, Jr., J. Gauger, W. Starr, and V. Vali; Magnetic Channeling of a Strong Shock, F. R. Scott, W. P. Basman, E. M. Little, and D. B. Thomson; Hydromagnetic Effects in Couette and Stokes Flow, H. W. Liepmann.

MATERIALS

Materials Handbook. Corning Glass Works. Corning, N.Y., 1958. 1 vol. (loose-leaf), diagrs.

This handbook presents data on a group of products representative of the more than 75,000 varieties of glass, refractory ceramics, and glass-ceramics available from Corning Glass Works. Mechanical, electrical, chemical, and other properties are included wherever such data are currently available. As new data are obtained and new materials developed, supplementary pages will be issued.

Metals for Supersonic Aircraft and Missiles; Proceedings of the Conference Heat Tolerant Metals for Aerodynamic Applications, Held January 28 and 29, 1957, at the University of New Mexico, Under the Joint Sponsorship of American Society for Metals and University of New Mexico. D. W. Grobecker, Technical Editor. Cleveland, ASM, 1958. 432 pp., illus., diagrs., tables. $7.50.

Contents: (1) Problems Relating to the Need for Heat Tolerant Materials in Aerodynamic Applications, P. W. Rowe. (2) Metals for Structures Exposed to Aerodynamic Heating, Wolfgang H. Steurer. (3) Materials Property Requirements and Test Methods for Aerodynamic Applications, Louis Luini. (4) Kinetics of Oxidation in a Gas Stream, J. T. Waber. (5) Protective Metallic Coatings, Charles L. Faust. (6) The Light Metals—Aluminum, Magnesium, Titanium, R. R. Kennedy. (7) AISI and Stainless Steels for Aerodynamic Applications, J. T. Milek and B. L. Molander. (8) Nickel and Cobalt Base Alloys, F. S. Badger and G. A. Fritzlen. (9) The Properties of Eleven Less Common Metals, B. A. Rogers. (10) Fundamentals of Metal-Ceramic Combinations (Cermets), Henry H. Hausner. (11) Specific Ceramics and Cermets of Promise, Malcolm F. Judkins. (12) Review, Summary and Evaluation J. R. Townsend.

The Structure of Steel, A Simple Explanation for Students, Engineers, and Buyers of Steel. Edwin Gregory and Eric N. Simons. New York, Philosophical Library, 1958. 176 pp., illus., diagrs., tables. $10.

This simple, nontechnical explanation of the metallurgical structure of the various steels and steel alloys is intended especially for those other than metallurgists. The book shows how the properties of any given steel will depend on both its composition and its treatment during manufacture, and attention is therefore given to both these aspects. The basic chemistry of iron and steel is outlined, with references to the effects of cooling from the liquid state and to atomic and crystalline structure. Impurities found in steels and their effects are explained, as well as the effects of the various processes of mechanical working. The range of modern alloy steels is reviewed, and particular attention is given to stainless steels and heat-resisting steels.

Contents: Introduction. (1) Constitution of Iron-Carbon Alloys. (2) Critical Points. (3) Crystalline Forms. (4) Impurities of Steel. (5) Alloy Steels. (6) Structure and Mechanical Characteristics. (7) Microscopic Structure. (8) Principles of Testing. (9) Mechanical Test Methods. (10) Non-Mechanical Test Methods. (11) Heat-Treatment Processes. (12) Corrosion: Stainless Steels. (13) Structural Effects of Mechanical Working. *Appendix:* Tables of Hardness Numbers. Glossary of Terms. Bibliography. Index.

Technology of Columbium (Niobium); Papers Presented at the Symposium on Columbium (Niobium) of the Electrothermics and Metallurgy Division of the Electrochemical Society, May 15–16, 1958, Washington, D.C. Edited by B. W. Gonser and E. M. Sherwood. Sponsored by the Electrochemical Society, Inc. New York, John Wiley & Sons, Inc., 1958. 120 pp., illus., diagrs., tables. $7.00.

Contents: Introduction, Bruce W. Gonser. The Element Columbium and its Compounds, James R. Darnell and L. F. Yntema. Sources of Columbium, Kenneth B. Higbie. Economic Aspects and the Supply Situation for Columbium, Ronald L. Charmichael. A Review of the Extractive Metallurgy of Niobium, M. E. Sibert, A. J. Kolk, Jr., and M. A. Steinberg. Niobium in Nuclear Reactors, E. Epremian. Recent Developments in Separating Tantalum and Niobium by Solvent Extraction, Joan L. Tews and Sherman L. May. Investigation of Electrolytic Processes for Preparation of High Purity Niobium Metal, A. J. Kolk, Jr., M. E. Sibert, and M. A. Steinberg. Analysis for Certain Metallic Impurities in Niobium, James F. Reed. The Determination of Nitrogen and Oxygen in Niobium, William F. Harris. Tensile Properties and Rolling Textures of Niobium Sheet, F. J. Anders, Jr., and W. I. Pollock. The Ductile-to-Brittle Transition in Niobium, E. T. Wessel and D. D. Lawthers. The Effect of Rare Earth Metal Additions on the Ductility of Arc-Melted Group Va Metals, J. W. Semmel, Jr. Electroplated Metals on Niobium, John G. Beach. The Development of Oxidation-Resistant Niobium Alloys, Harry P. Kling. Preliminary Study of the Effect of Binary Alloy Additions on the Oxidation Resistance of Columbium, Francis J. Clauss and Charles A. Barrett. Oxidation of Columbium-Chromium Alloys at Elevated Temperatures, Charles A. Barrett and Francis J. Clauss. Vacuum Reactions of Niobium During Sintering, William D. Klopp, Chester T. Sims, and Robert I. Jaffee.

MATHEMATICS

Contributions to the Theory of Nonlinear Oscillations, Vol. 4. Edited by S. Lefschetz. (*Annals of Mathematics Studies, No. 41.*) Princeton, N.J., Princeton University Press, 1958. 211 pp., diagrs. $3.75.

Contents: Preface, Solomon Lefschetz. (1) On the Non-Linear Difference-Differential Equation $y'(t) = [A - By(t - \tau)]y(t)$, S. Kakutani and L. Markus. (2) On the Critical Points of a Class of Differential Equations, Solomon Lefschetz. (3) Optimal Discontinuous Forcing Terms, D. Bushaw. (4) On the Structure of Symmetric Periodic Solutions of Conservative Systems, with Applications, René DeVogelaere. (5) Asymptotic Behavior of Solutions of Canonical Systems Near a Closed, Unstable Orbit, D. L. Slotnick. (6) Small Periodic Perturbations of an Autonomous System of Vector Equations, Walter T. Kyner. (7) Rotated Vector Field and an Equation for Relaxation Oscillations, George Seifert. (8) A Survey of Lyapunov's Second Method, H. A. Antosiewicz. (9) On Phase Portraits of Critical Points in *n*-Space, Pinchas Mendelson. (10) On Non-Linear Repulsive Forces, Robert W. Bass.

METEOROLOGY

Final Report of the Advisory Committee on Weather Control, Howard T. Orville, Chairman. Washington, Superintendent of Documents, 1958. Vol. 1, 32 pp.; Vol. 2, 422 pp.; illus., diagrs., tables. $2.75 the set.

The Advisory Committee on Weather Control was created by Act of Congress in 1953 to study and evaluate public and private experiments in weather modification. Its membership consists of five Presidential appointees from the fields of science, agriculture, and business. *Volume I* contains the Committee's findings and recommendations. *Volume II* contains the detailed technical reports which in part form the basis for the findings and recommendations. The second volume also contains a report of the legal situation, a design for the study of possible economic implications, and other special studies and reports. Its major content, however, comprises what the Committee considers to be valuable information in the field of weather modification.

MISSILES

The United States Air Force Report on the Ballistic Missile, Its Technology, Logistics and Strategy. Edited by Kenneth F. Gantz. Garden City, N.Y., Doubleday & Co., Inc., 1958. 338 pp., illus., diagrs. $4.00.

In this review of the ballistic missile program of the United States Air Force, officers in charge of its various phases report on the nature of the missile, its development and production, its use as a weapon by the Strategic Air Command, and the projected Air Force program of space operations which the long-range missile now makes possible. Many of the contributions in the volume have already appeared as articles in the *Air University Quarterly Review*, which is the professional journal of the USAF in strategy, tactics, and techniques.

Contents: Chronology of Major Events in the Development of Air Force Ballistic Missiles. Missiles and the Race Toward Space, Gen. Thomas D. White. The USAF Ballistic Missile Program, Major Gen. Bernard A. Schriever. Air Force Missile Experience, Col. Edward N. Hall. Missiles in Perspective, Col. Claude E. Putnam. Command and Control of Ballistic Missiles, Major Gen. Charles M. McCorkle. Organizing and Manning Ballistic Missile Units, Lt. Col. William L. Anderson. The Ballistic Missile and Operational Capability, Major Roy L. Ferguson, Jr. Misslemen—Present and Future, Col. Allen W. Stephens. The Ballistic Missile Test Program, Lt. Col. Edward A. Swanke and Lt. Col. Richard K. Jacobson. Logistics for the Ballistic Missile, Major Gen. Ben I. Funk. Impact of the Ballistic Missile on Warfare, Col. Alexander Sheridan. Impact of the Ballistic

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Missile on Defense, Col. Harvey W. C. Shelton. Impact of the Ballistic Missile on Industry: (1) From the Air Force's Viewpoint, Major Gen. Ben I. Funk. (2) From an Airframe Manufacturer's Viewpoint, The Martin Co. (3) From a Rocket Engine Producer's Viewpoint, Rocketdyne Division, North American Aviation Co. (4) From the Electronic Industry's Viewpoint, An Electronic Industry Symposium. SAC and the Ballistic Missile, Gen. Thomas S. Power.

Appendices: (1) Notes on Technical Aspects of Ballistic Missiles, The Ramo-Wooldridge Corp. (2) Fundamental Equations of Force Survival, Col. Robert D. Bowers. (3) The Ballistic Missile and Its Elusive Targets, Major Kenneth A. Smith. (4) The USAF Reports to Congress, Compiled by Lt. Col. Kenneth F. Gantz. (5) A Glossary of Terms Related to the Ballistic Missile, Compiled by Lt. Col. Kenneth F. Gantz. (6) Biographical Notes.

OPERATIONS RESEARCH

Operational Research in Practice, Report of a NATO Conference; (The NATO Conference on Operational Research Sponsored by AGARD and SHAPE, April 7-12, 1957, Paris). Edited by Max Davies and Michel Verhulst. London; New York, Pergamon Press, 1958. 201 pp., illus., diagrs., tables. $12.

This book gives an account of what operational research can do and describes how various operational research techniques have been applied to specific problems and groups of problems. A feature of the volume is that both papers and discussions tend to proceed from the military basis of operations research (in which it had its origins during World War II) to the civilian and industrial applications. As this work is directed at administrators and executives in NATO countries rather than operational workers, it is of particular value to those who want a broad view of the present usefulness of operational research and an insight into its potential and philosophy.

Contents: Meaning and Function of Operational Research. The Need for Operational Research, Solly Zuckerman. The Status of Operational Research in NATO Nations: Italy (Forces Armées), P. Supino; Netherlands, C. de Jongh; Denmark, E. W. Lennholm; Norway, F. Möller; Turkey, Fuat Ulug; Germany, Theodore Benecke; France, A. Kreweras. Development Planning—Operational Research Aspects, James E. Lipp. Some Examples of Systems Analysis, Handel Davies and K. E. Silman. Scientific Aids to Decision Making—A Perspective, J. R. Goldstein. Methode d'Evaluation de l'Efficacité d'un Système de Renseignement de Defense Aérienne, Colonel Ferré. Methods of Air Defence Over Germany in World War II, Theodore Benecke. Systems of Evaluation and Military Planning, J. W. Abrams. Linear Programing, Merrill M. Flood. Logistic and Transport Operations, Glen D. Camp. Economie et Strategie, P. Masse. La Recherche Opérationelle en Action, Francesco Brambilla. War Games, Robert D. Specht Organization for Operational Research in the United Kingdom, G. N. Gadsby. Organization for Operational Research in the U.S.A., Joseph F. McCloskey. Selection and Training of Operational Research Scientists, Hugh M. Cole. Future Fields for Operational Research in the NATO Nations, H. A. Sargeaunt. Indexes.

PHYSICS

Cosmic Ray Vibrations. L. I. Dorman. (Translation of *Variatsii kosmicheskih luchey.* Moscow, State Publishing House for Technical and Theoretical Literature, 1957.) Wright-Patterson AFB, Ohio, Technical Documents Liaison Office, MCLTD, Feb., 1958. 726 pp., illus., diagrs., tables.

This book gives the experimental and theoretical methods of investigating the variations of cosmic rays (time variations of their intensity), systematizes and analyzes the accumulated experimental material, and critically considers the hypotheses that have been proposed for the origin of various types of variations. A theory is proposed for the origin of the variations, and their correlation with various geophysical and astrophysical phenomena is examined, in particular their correlation with the properties of the solar corpuscular streams and with the electromagnetic conditions in the neighborhood of the earth, in the solid atmosphere, in interplanetary space, and in the galaxy.

It is expected that the book will be of interest to scientists occupied with cosmic-ray physics, astrophysics, geophysics, or meteorology; to students of advanced courses in these specialties; and to workers in the network of stations for continuous cosmic-ray observations.

POWER PLANTS

Aircraft Missile Propulsion. Vol. 2, The Gas Turbine Power Plant, the Turboprop, Turbojet, Ramjet, and Rocket Engines. M. J. Zucrow. New York, John Wiley & Sons, Inc., 1958. 636 pp., diagrs., tables. $13.

This is the second volume of a three-volume work written primarily for the engineering student and for engineers who are not specialists in propulsion. The present book discusses the methods for

(Continued on page 113)

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Personnel Opportunities

This section is for the use of individual members of the Institute seeking new connections and eligible organizations offering employment to specialists in the aero/space industry. Any member or eligible organization may have requirements listed without charge by writing to the Secretary of the Institute.

Wanted

Structural Test and Analysis—Will be required to perform theoretical and experimental stress analyses on high-speed rotating parts, complex pressure vessels, and hydromechanical servomechanisms for jet aircraft accessory equipment. Will provide an opportunity to become familiar with programming procedures for IBM 704 and 705 electronic data processing machines. Experimental work will involve use of such tools as stresscoat, bonded wire strain gages, and photoelasticity equipment. B.S. degree in Mechanical Engineering required, and graduate work or experience in theoretical and applied mechanics desirable. Please send reply to: Engineering Employment Supervisor, Hamilton Standard Division, United Aircraft Corporation, Bradley Field Road, Windsor Locks, Conn.

Senior Aeroelasticity Engineer—Evaluate new airplane and missile designs from an aeroelastic standpoint—contribute to the aeroelastic design of production weapon systems, including considerations of vibration, flutter and static aeroelasticity. **Acoustic Specialist**—Required to predict environmental vibration and acoustical levels in and around the aircraft and to predict the response of equipment and aircraft structure to these inputs. Design of vibration isolators and acoustic insulation. You will be supported in these activities by well-trained mathematicians and engineers. **Flutter Model Designer**—Assume complete responsibility for the engineering design and testing of subsonic, transonic, and supersonic flutter models. Complete model shop test facilities available as well as supporting staff. Send replies to: R. J. Theibert, Engineering Personnel, North American Aviation, Inc., 4300 East Fifth Avenue, Columbus 16, Ohio.

The number preceding the notice represents the Box Number of the Institute of the Aeronautical Sciences to which inquiries should be addressed.

Teaching Positions—Applications are being received for two permanent positions in the Department of Aeronautical Engineering at the University of Alabama. Applicants for one position should have advanced degrees. The other opening could be filled by a person holding only a Bachelor's degree if he were to show promise of becoming a successful teacher. Opportunities for consulting and research are available, both of which are encouraged. A person who has earned a Ph.D. within recent years would sense an unusually attractive opportunity to develop a graduate program and teach in his chosen field. Salaries will depend on qualifications—up to $9,000 for nine months for a professor. The usual academic tenure regulations will apply, and the University contributes toward retirement and insurance. Please address inquiries to: Colgan H. Bryan, Head, Department of Aeronautical Engineering, P. O. Box 1461, University, Alabama.

Engineers—Rotary Wing Engineers and Designers; Stress Engineers—with experience in land load; **Designers**—with experience in control system; **Dynamicists**—with experience in stability and control. Send résumé to: Leonard Goland, Director of Research and Development, Kellett Aircraft Corp., P.O. Box 35, Willow Grove, Pa.

Engineers and Scientists—Douglas Aircraft Company, Inc., designers and developers of missiles and ground support equipment, commercial and military aircraft, urgently needs large numbers of aeronautical, electrical, electronic, mechanical, chemical, metallurgical, and civil engineers; physicists and mathematicians; graduates or experienced near-graduates. There are openings in design, development, research and test, and in the fields of acoustics, hydraulics, electronics, thermodynamics, propulsion, computers, systems analysis, aerodynamics, dynamics, etc. Plants are located at Santa Monica, Long Beach, and El Segundo, Calif.; Tulsa, Okla.; and Charlotte, N. C. Missiles Field Stations are at Vandenburg AFB, Santa Maria, Calif.; Sacramento, Calif.; White Sands, N.M.; and Cocoa, Fla. Aircraft Test at Edwards AFB, Calif. Mail résumé to: C. C. LaVene, Staff Assistant to Vice-President—Engineering

RESEARCH ENGINEERS

The Engineering Mechanics Department of Southwest Research Institute has a limited number of attractive positions for well qualified personnel. These positions offer an outstanding opportunity for challenging work in aeronautical dynamics, theoretical and applied mechanics and applied mathematics. A wide range of assignments on programs related to missiles, ships, submarines, space vehicles, nuclear power, pressure vessels, off-shore drilling systems, and weapons effects accelerate the rate of professional progress.

Candidates should have an M.S. or Ph.D. Degree with research experience being desirable. Please send resume and salary requirements to:

Mr. R. C. Mays, *Personnel Director*
Southwest Research Institute
8500 Culebra Road
San Antonio 7, Texas

SENIOR FLUID MECHANICS ENGINEER/SCIENTIST—with knowledge of viscid and non-viscid gas flows, both steady and unsteady. Problems involve high-speed heat transfer; classical potential theory; slender-body theory; shock wave buffeting; and refraction.

STRUCTURAL DYNAMICIST AND STRESS ANALYST—with knowledge of aircraft and missile structural design and all aeroelastic phenomena. Problems involving loads and forces in flexible airframes responding to dynamic inputs. Also, thermal stresses combined with dynamic loading conditions.

The opportunity to select problems of individual interest also exists. Please send resume to:

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Senior Vibration & Flutter Engineers—B.S. or M.S. in A.E., Applied Mechanics, Physics, with 5–10 years experience in theoretical flutter analysis of high-speed aircraft and missiles, flight flutter analysis of high speed aircraft and missiles, flight flutter testing, or vibration theory and test. To direct engineers in conducting complete vibration and flutter analyses on aircraft and/or missiles. **Senior Dynamics Engineers**—B.S. or M.S. in A.E. or Applied Mechanics with minimum of 5 years experience in aircraft or missile dynamics. To direct engineers in conducting analytical investigations of dynamic aspects of aircraft flying qualities, missile dynamics and STOL and VTOL stability control. U.S. Citizenship required. Salary in accordance with background and experience. Apply to: A. Wilder, Engineering Personnel Director, Dept. 11, Grumman Aircraft Engineering Corporation, Bethpage, L.I., N.Y.

Electronic Engineers and Physicists—Positions are open on the research and development staff for senior and junior electronic engineers and physicists. Unusually interesting and challenging R&D projects in advanced data processing systems and electronic circuitry. Excellent working conditions. Salaries at high industrial levels, commensurate with experience and ability. U.S. citizenship required. Applications are kept in strict confidence. Send résumé and salary requirement to Code 13, Paul Rosenberg Associates, 100 Stevens Ave., Mount Vernon, N.Y.

Engineers—Engineers, Scientists, and Mathematicians. Diversified positions available involving research in magneto-hydrodynamics, high-temperature gas dynamics, and thermoaero engineering for advanced propulsion and space systems; design and development involving mechanical, aerothermo design and analysis, control systems, performance analysis, test, development, and project engineering; applied mathematics and programing in a computer (IBM 704) and mathematics group. Send résumé to Felix Gardner, Fairchild Engine Division, Fairchild Engine and Airplane Corp., Deer Park, L.I., N.Y.

Hydrodynamicists—Experience in aircraft or marine hydrodynamics is desirable. However, aeronautical engineers with aerodynamics experience will be considered. Minimum of 2 years required. Projects now include research and development in seaplanes and several phases of Polaris program. **Preliminary Design Engineers**—5 to 10 years' experience in design and analysis. Technical writing ability is essential. These positions offer excellent growth opportunities with expanding prime contractor located in New York City. Contact: Chief Mechanical Engineer, Edo Corp., 13–10 111th St., College Point, L.I., N.Y.

891. Teaching and Research—Available for February 1959, positions with rank of Assistant Professors, Instructors, and part-time Graduate Assistants in engineering mechanics for both teaching and research. Excellent opportunities for graduate study.

Available

884. Physicist—B.S. (Physics) and M.A. (Math.); age 35. Employed as aeronautical research engineer (flight systems) GS-14, Step 6; Career appointment at $12,555. Nature of employment; operations research/astronautics. Two years in grade at present classification; also 1/2 year in grade as Supervisory Physicist GS-14. Other: 2 years as Physicist (General), 3 years as Physicist (Optics), 1½ years as research optical and illuminating engineer, and 2 years' military service (Radioman). Desires a career appointment to a GS-15 position or appropriate employment in private industry. Will consider relocation. Will forward résumé on request.

886. Washington Representative—Exceptionally wide span of high-level technical-management experience in Government and in aeronautical industry R&D, long-range planning and customer relation activities. Graduate aeronautical/mechanical engineer with mature judgment, plenty of initiative and drive, and unbounded ambition. Total of over 20 years of professional background in aircraft-missile-space vehicle systems; with particularly outstanding capability and knowledge of propulsion systems requirements, design, development, engineering, operational usage, and related problems. Conversant and current on space problems and R&D, and complex of Government agencies and specific personnel concerned with various phases of National Space Program. Seeks major assignment and senior responsibility as Washington Representative of company needing new approach and/or better coverage and contacts with Government R&D and long-range planning groups. Correspondence strictly confidential. Résumé or personal interview on request.

887. Management Assistant—Age 31. B.S. degree in Industrial Administration from Yale University. 7 years aircraft industry experience in close association with engineering and research. Registered Patent Agent, 4 years experience preparing and supervising the prosecution of patent applications. Presently responsible for the handling of all patent matters including contractural obligations. Current and historical knowledge of developments in the airframe and rotary wing fields. Previous successful sales experience and sales engineering training program in industrial products. Proved administrative ability includes the current supervision of two departments with continual high level association with management. Desires position of greater responsibility and promise. Southern California area preferred.

888. Executive—Experience as Vice-President–Operations of an electronic firm. B.S. & M.S. in Aero., R.P.I. Unusual combination of abilities in technical, management, and business activities in electronics, missiles, and rocket motors. Familiar with astrophysics and advanced space vehicle concepts; capable of forming or directing a space division; as assistant to the president or vice-president; director of advanced planning. All correspondence strictly confidential.

890. Aeronautical Engineer—Analytical engigineer with Ph.D., M.A.E., 18 years experience in aerodynamics, dynamics, structures, thermodynamics, dealing with research and development of subsonic through hypersonic and ballistic aircraft and missiles, much of it at progressively high supervisory levels. Numerous publications. Interested in position involving responsibility for these areas with established aircraft or missile manufacturer, minimum salary of $20,000. Detailed résumé furnished upon request accompanied by brief description of position under consideration.

✦ ✦ ✦

Reviews

(Continued from page 102)

in French and Russian. Study of the deflection of a stream of ideal incompressible fluid in steady motion. Includes development of a numerical method, presentation of an illustrative example, and evaluation of theoretical and numerical results.

Water-Based Aircraft

Ultraschallwelle am Tragflügelprofil bei Hohlsog. II. F. Numachi. *Forschung Gebiete Ing., Ausg. A*, No. 3, 1958, pp. 73–89. In German. Discussion of tests showing the effect of static pressure and water temperature on the frequency dependence of the mean sound pressure. The tests were performed as part of an investigation on ultrasonic waves produced by cavitation behind hydrofoils.

Kavitationsblasen und Ultraschallwellen am Tragflügelprofil. F. Numachi. *Forschung Gebiete Ing., Ausg. A*, No. 4, 1958, pp. 125–132. In German. Investigation of the development of cavitation bubbles on hydrofoils studied in a water tunnel by means of high-speed photography.

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analyzing and determining the performance characteristics of the gas-turbine power plant, the turboprop engine, the turbojet engine, the ram-jet engine, and liquid-propellant and solid-propellant rocket engines. The material is based on courses in jet propulsion given by the author since 1946 to graduate students at Purdue University and contains the following features: the notation for each chapter precedes the chapter; a large number of illustrative examples have been worked out completely; derivations of principal equations are explained in detail; numerous exercise problems are included with their answers; and references are presented at the end of each chapter as a guide to further study.

Dr. Zucrow is Professor of Gas Turbines and Jet Propulsion at Purdue.

TECHNICAL DRAWING

Technical Drawing. 4th Ed. Frederick E. Giesecke, Alva Mitchell, and Henry Cecil Spencer. New York, The Macmillan Co., 1958. 844 pp., illus., diagrs. $10.

This new edition of a standard reference covers all the basic techniques in technical drawing and incorporates the latest standards and practices, including the ASA Y-14 drafting standards. Many of the chapters are new or have been completely revised and reorganized, and the text contains over 700 completely new figures and air-brushed illustrations.

VIBRATION

Engineering Vibrations, With Applications to Structures and Machinery. Lydik S. Jacobsen and Robert S. Ayre. New York, McGraw-Hill Book Co., Inc., 1958. 564 pp., diagrs., tables. $10.

This introduction to the analysis of technical vibrations of linear and nonlinear systems is intended for the practicing engineer and the student. In view of the modern interest in shock problems, the book emphasizes the transient state of motion and considers the steady state a special one. However, many cases of steady-state vibration are included. Classical analytical methods are used where feasible, and extensive use is made of approximate methods, including the phase-plane graphical method for the step-by-step solution of transient problems in both linear and nonlinear systems and the Ritz averaging method for solving steady-state nonlinear problems.

The authors are, respectively, Professor and Chairman, Department of Mechanical Engineering, Stanford University; and Professor and Chairman, Department of Civil Engineering, The Johns Hopkins University.

Random Vibration, Notes for the M.I.T. Special Summer Program, June 23–July 3, 1958. Edited by Stephen H. Crandall. Cambridge, Mass., The Technology Press of the Massachusetts Institute of Technology, 1958. 406 pp., diagrs., tables. $10.

These notes were written especially for engineers who are already familar with classical vibration theory and who need an introduction to the random vibration problem which has become important in recent years in the design and testing of missiles, jet aircraft, and other vehicles subject to random loadings. All the required basic notions of probability and statistics are developed from first principles without assuming any previous training in statistics. The first six chapters present the basic principles and background. The last six chapters discuss specific problems of design and testing.

Contents: (1) Mechanical Vibrations with Deterministic Excitation, Stephen H. Crandall. (2) The Description of Random Processes, William M. Siebert. (3) Stochastic Processes of Mechanical Origin, Hillel Poritsky. (4) Statistical Properties of Response to Random Vibration, Stephen H. Crandall. (5) Structural Damping, Theodore A. Pian. (6) Fatigue of Metals, Fank A. McClintock. (7) Instrumentation for Random Vibration Analysis, Thomas P. Rona. (8) On the Response of Structures to Random Pressures and to Jet Noise in Particular, Alan Powell. (9) Estimation of Sound-Induced Missile Vibrations, Ira Dyer. (10) The Basis for the Design of Simulation Equipment, Kenneth J. Metzgar. (11) Technical Characteristics of Simulation Equipment, Dorman E. Priest. (12) Mechanical Design for Random Loading, Robert M. Mains.

1958 National Telemetering Conference Report

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XUM

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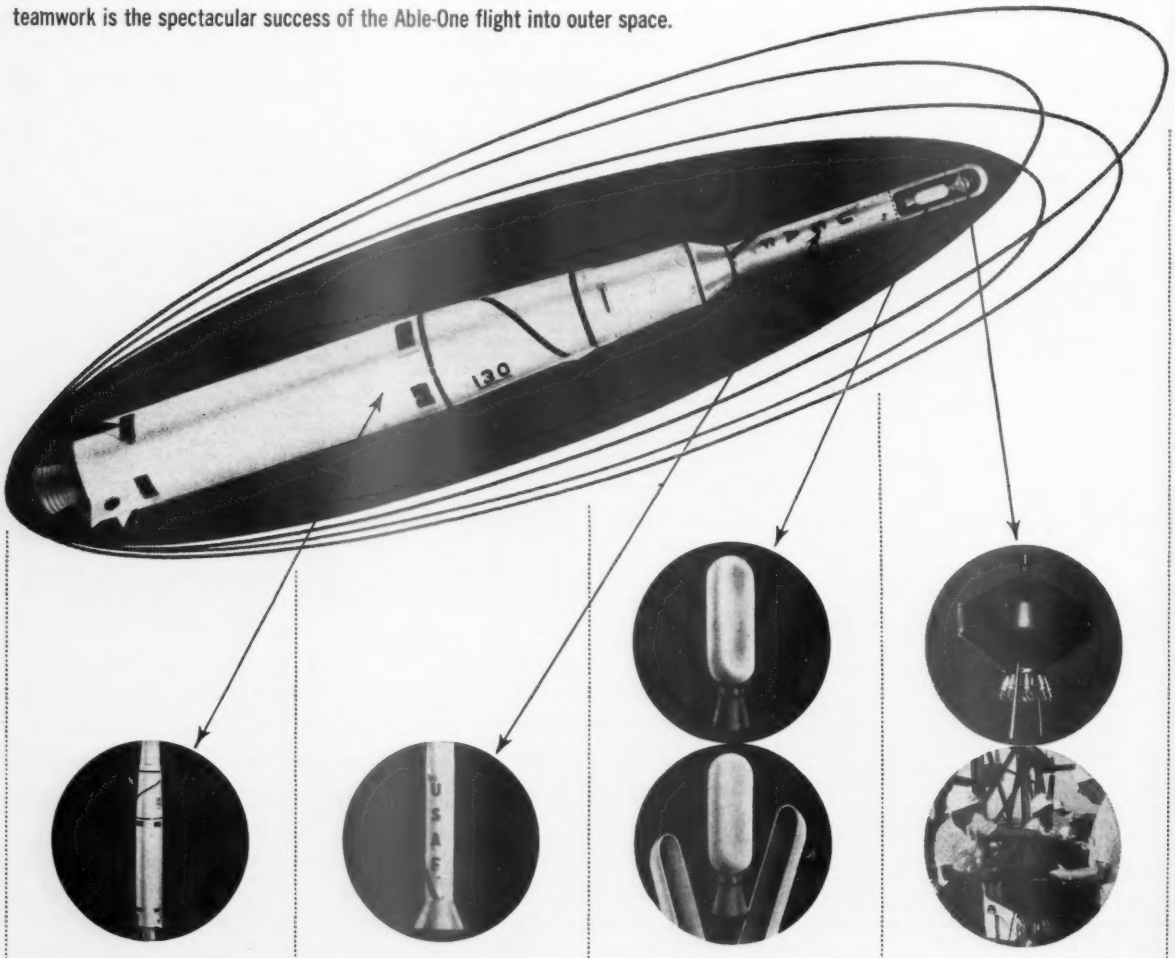
Preparation and execution of an undertaking such as the United States' IGY space probe demanded the participation and exceptional efforts of 52 scientific and industrial firms and the Armed Forces. The Advanced Research Projects Agency and the AFBMD assigned Space Technology Laboratories the responsibility for the project which was carried out under the overall direction of the National Aeronautics and Space Agency. One measure of this teamwork is the spectacular success of the Able-One flight into outer space.



1st stage: Vehicle, Douglas Aircraft **Thor** IRBM; propulsion, Rocketdyne; airframe, control, electrical and instrumentation, Douglas Aircraft; assembly, integration, and checkout, Douglas Aircraft.

2nd stage: Propulsion system and tanks, Aerojet-General; control, electrical, instrumentation, accelerometer shutoff, and spin rocket systems, STL; assembly integration, and checkout, STL.

3rd stage: Rocket motor, U. S. Navy Bureau of Ordnance and Allegheny Ballistic Laboratory; structure and electrical, STL; assembly, integration, and checkout, STL; ground testing, USAF's Arnold Engineering Development Center.

Payload: Design and production of **Pioneer**, the payload of the Able-One vehicle, was conducted by STL in addition to its overall technical direction and systems engineering responsibility of the Air Force Ballistic Missile Division project. This highly sophisticated package included a NOTS TV camera and transmitter and Thiokol rocket motor.

Inquiries concerning openings on our staff will be welcomed by

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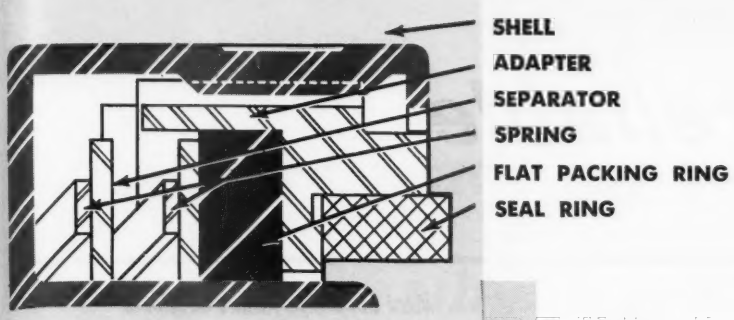

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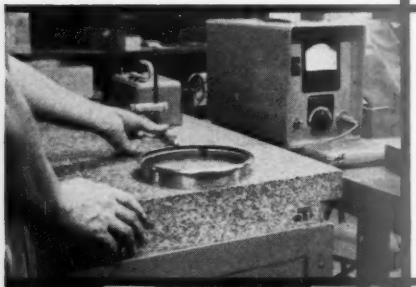

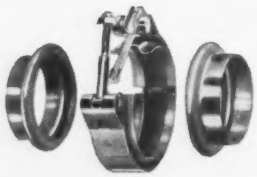

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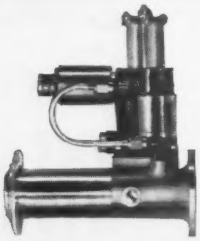

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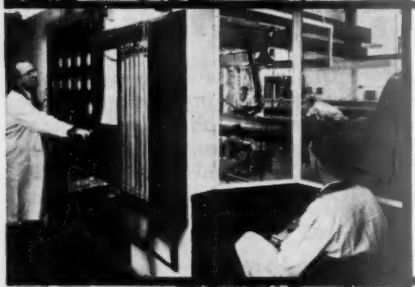

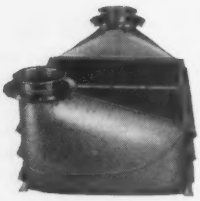

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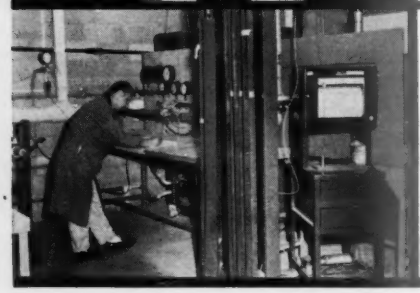

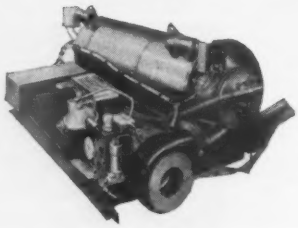

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Temco | AIRCRAFT DALLAS

Now on Duty with the Navy . . Temco's TT-1 Primary Jet Trainer

Now on duty with the Navy, Temco's TT-1 Pinto is an advance-guard aircraft . . first to introduce the concept of an all-jet syllabus for aviation training. And already, while still under evaluation, the Pinto is *growing* . . stepping up greatly in power, agility and safety.

Designed from the very beginning for *growth through simple modification,* the production Pinto will be equipped with a Continental J69-T-25 engine in place of its J69-T-2. This engine changeover will be accomplished without noticeable change in outward appearance, without significant internal changes. Further modifications will extend the Pinto's ability to carry more equipment . . let it grow with the man . . make it capable of performing almost the entire primary/basic syllabus at considerably less than half the cost of any other jet trainer available or under development.

This sleek, speedy jet trainer was designed, developed and produced entirely by Temco. And while it is a prime example of the unusual talents and capabilities Temco possesses, it is just one phase of Temco's widely diversified work. Other phases are research and development in the field of advanced weapon systems . . new developments and fabrication techniques in stainless steel, titanium and other high temperature materials. All part of Temco's continued pioneering of the "total package" concept of design, tooling and production of aircraft and missiles . . of its complete weapons systems management capabilities.

Tomorrow's Need is Today's Challenge at..

TEMCO

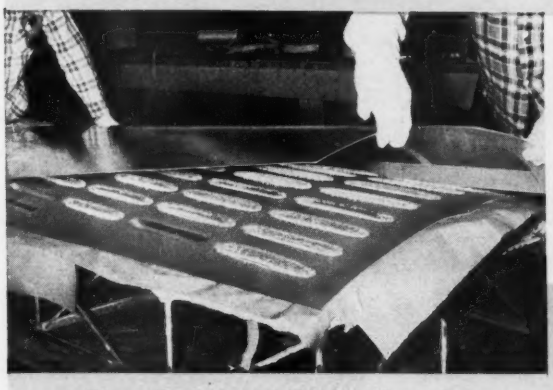
AIRCRAFT CORPORATION • DALLAS, TEXAS

XUM

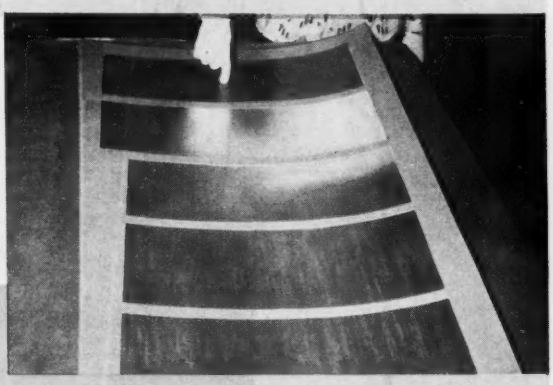
In the new supersonic B-58 Hustler:

The new B-58 Hustler is the first aircraft to take maximum advantage of Epon resin bonding strength.

Epon Adhesive 422 tape is cut to match the template for the outer skin section of Convair's new B-58 Hustler.



Epon adhesive tape is fitted to close tolerances; is used to bond metal to core and metal to metal.



Here, the "corncob," a honeycomb insert embedded into the fuselage bead, is bonded by Epon 422 adhesive tape to the inner skin.

Epon® resin-bonded structures resist skin temperatures up to 500°F!

The new B-58 Hustler, made by Convair Division, General Dynamics Corp., is a significant design achievement . . . and is the first supersonic aircraft to make maximum use of Epon resin-bonded "sandwiches" of aluminum skin-fiberglas honeycomb panels.

Epon Adhesive 422, a glass-supported tape, was chosen to meet the unique requirements for metal-to-core bonding because:

- **High-temperature resistance**—Epon Adhesive 422 maintains a high degree of strength from −70°F to 500°F.
- **Light weight**—With high-strength Epon Adhesive 422, honeycomb panels can replace heavy substructure and the thick skin riveted to it, providing a substantial overall weight saving.
- **Lowered air resistance**—Epon Adhesive 422 makes possible aerodynamically smooth surfaces.
- **Eliminates critical stress problems**—Stress is uniform over the entire Epon resin-bonded surface. Local stress concentration which occurs with conventional fasteners is eliminated.

Perhaps Epon Adhesive 422 or other Epon resins may be able to solve a design problem for you. For information, write us now.

Epon resins are the epoxy polymers made exclusively by Shell Chemical Corporation.

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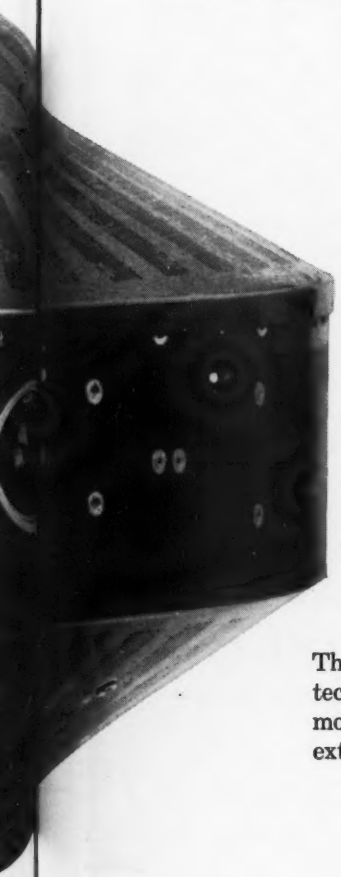

HEXCEL—world leader in honeycomb, basic source for aluminum, stainless, glass fabric and cotton honeycomb . . . largest tech service staff . . . R & D trailblazers . . . high temperature honeycomb pioneers . . . product superiority from patented processes, special machinery . . . largest manufacturing facilities.

The complex instrumentation of Pioneer was contained and protected by Hexcel fiberglass honeycomb. This sandwich structure, molded by Summit Industries of Gardena, California, gave Pioneer extraordinary strength with an absolute minimum of weight.

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NEW

SOUND-LEVEL METER

FEATURING:

NEW Package — Smaller, lighter, easier to handle; only 7½ lbs. with batteries.

NEW Microphone — Shure 98B99 Rochelle-salt-crystal type has smooth response from 20c to 8 kc.

NEW Horizontal Position for Microphone — keeps microphone away from instrument cabinet and operator's body; minimizes disturbance of sound-field.

NEW Calibration Check — Built-in reference circuit eliminates need for 115-volt, 60-cycle line; permits convenient instrument calibration anywhere.

NEW Calibrated Microphone Sensitivity Adjustment — changes reference voltage allowing quick and convenient resetting of amplifier gain when using specialized microphones.

IMPROVED Signal-To-Noise Ratio — Achieved by amplifier redesign. Microphonics caused by vibration and air-borne sounds have been further reduced through use of low-noise cable and improved shock and vibration mountings.

IMPROVED Sound-Level Range — Direct reading from 24 to 150 db.

IMPROVED Stability — A voltage-reference diode maintains constant plate voltage on first two amplifier stages. Second stage is now a pentode, permitting greater gain and allowing the use of more feedback around main amplifier. The output stage has been changed to a transistor emitter-follower.

IMPROVED Frequency Response results from —

1. Smoother microphone frequency characteristics
2. New attenuator with improved frequency response
3. New amplifier with greater bandwidth
4. Weighting networks that fit design center of ASA characteristics more closely
5. New indicating meter with no frequency error

IMPROVED Waveform Response — A new quasi-rms-reading meter approaches true rms response more closely than do older types.

Type 1551-B

Sound-Level Meter $395

PLUS . . . SOUND-LEVEL-METER ACCESSORIES

- **Spectrum Analyzers** for narrow-band, broad-band, and impact-noise measurements.
- **Condenser and Dynamic Microphones** for measurements to 200 db and for better frequency response — dynamic microphone for use with long cable runs.
- **External A-C Power Supply** where continuous use of Sound-Level-Meter is required; mounts directly on meter end.
- **Vibration Pickup** for measurement of vibrating-body displacement, velocity, and acceleration.
- **Sound-Level Calibrator** for establishing overall sensitivity from Sound-Level-Meter microphone to indicating meter.
- **New Leather Carrying Case** protects 1551-B in transit, has strap for shoulder carry; upon swinging cover flap open, instrument is ready to use.

Write for the G-R Sound Bulletin for complete information

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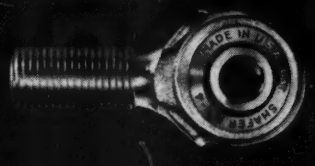
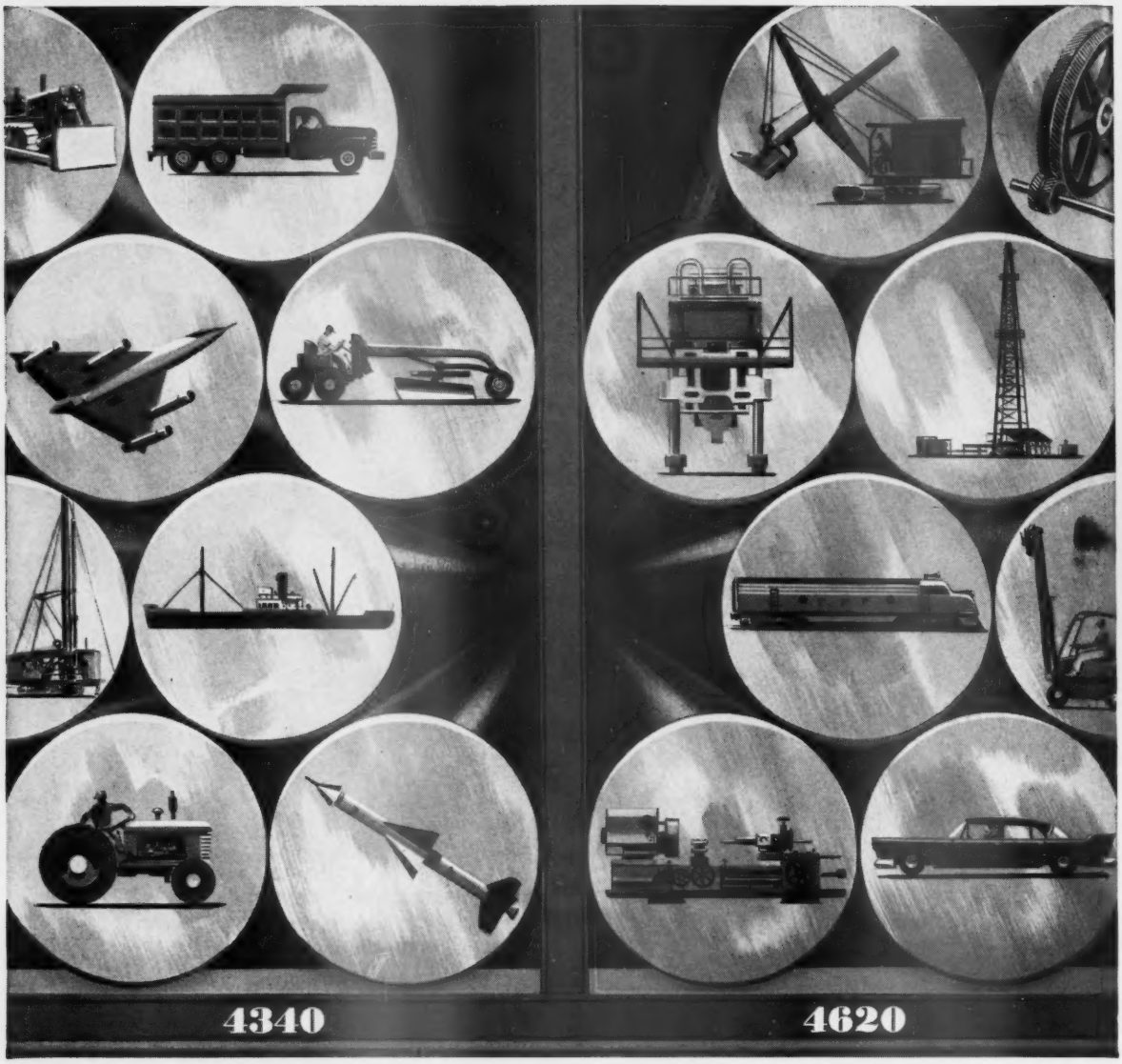
Whatever your requirements for aircraft bearing performance, call on Shafer's specialized design experience. Shafer Bearing Division, CHAIN Belt Company, 801 Burlington Avenue, Downers Grove, Illinois

SHAFER DIVISION OF CHAIN BELT COMPANY





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4340 stands alone among medium carbon steels in its ability to provide maximum strength, ductility, toughness and resistance to fatigue in parts of medium to heavy cross section.

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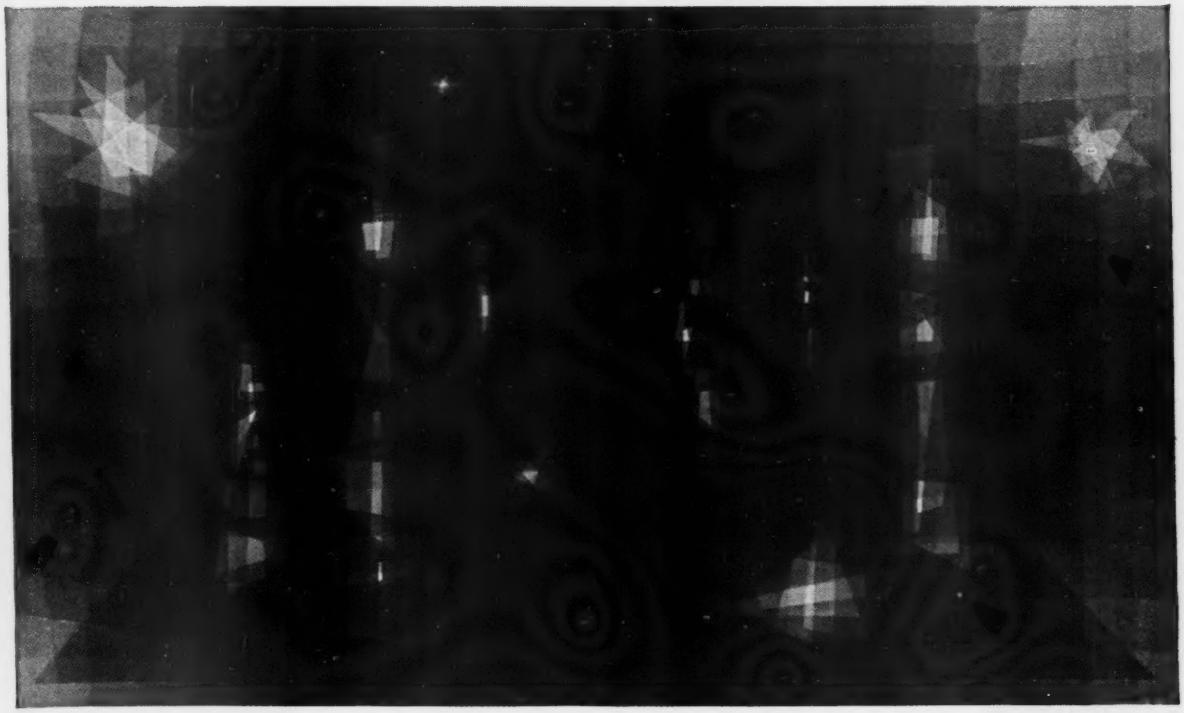

"SPACE CHESS," a painting by Simpson-Middleman, a doubly-gifted team of artists with a scientist's penetrating insight. They portray here "a chess-like game played in a segment of space on a skewed board with pieces of uncertain value against an unknown antagonist. The next move is unforeseen—it will come out of the dark—it will be history's most fateful gambit."

Space-age openings at Boeing

Advanced projects under contract at Boeing include Minuteman, a solid-propellant intercontinental ballistic missile, and Bomarc, America's longest-range area-defense supersonic guided missile system. Also underway at Boeing are studies for orbital, lunar and interplanetary systems.

These programs, along with extensive advanced research efforts at the frontiers of science, have created some of the nation's truly outstanding career opportunities for engineers and scientists.

There are openings at Boeing, now, in research, design, manufacturing and development, in such advanced areas as celestial mechanics, glide vehicles, space trajectories, high speed drag and heating effects in space flight and re-entry, anti-submarine warfare techniques, gas dynamics, nuclear physics, solid-propellant rocket engines, infrared techniques, anti-missile missiles, advanced electronics, and ion and plasma production and manipulation.

Boeing's space-age orientation, exemplified by advanced studies now underway in ballistic, orbital, lunar, interplanetary and advanced defense systems, has already laid a foundation for continuing leadership in the future. Engineers and scientists of all categories find at Boeing the kind of forward-striding environment that means dynamic career growth. Drop a note now to Mr. Stanley M. Little, Dept. A-83, Boeing Airplane Company, Seattle 24, Washington.

BOEING

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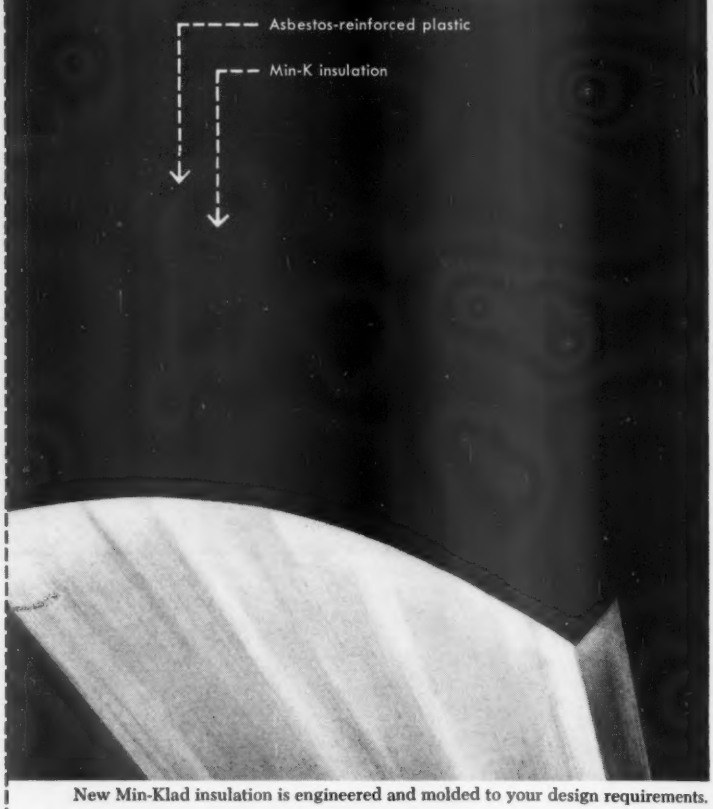
Johns-Manville announces new **MIN-KLAD** Insulation!

This one new product answers 4 basic thermal and mechanical requirements
low conductivity
high heat capacity plus erosion resistance
high strength



New Min-Klad insulation is engineered and molded to your design requirements.

Combines the capabilities of asbestos-reinforced plastic with the dramatically low conductivity of MIN-K insulation!

New Min-Klad insulation may well be the most significant advance ever made in missile and rocket insulation.

Developed by Johns-Manville research scientists, Min-Klad is the only product of its kind, a permanent lamination of the missile industry's two most effective high-temperature materials: 1) reinforced plastic and 2) J-M's recently developed Min-K insulation.

Does more than plastic alone

Min-Klad gives the missile designer all the advantages of high-temperature plastic: Strength, toughness, rigidity! Erosion resistance! High heat capacity! Yet Min-Klad does more.

It also insulates . . . and with dramatic effectiveness! Its insulating element is J-M's Min-K, an insulation with thermal conductivity that is lower than any other known insulation. Actually lower than the molecular conductivity of still air. And this conductivity (already less than half that of the best fibrous insulations) drops still further with altitude. At 10 miles, for example, it is decreased by as much as 40%, with further decreases at greater altitudes.

Wide range of applications

Min-Klad offers the missile and rocket designer a rich choice of heat-control possibilities. It may be used for a part that must insulate, yet have the structural advantages of plastic. Where requirements call for a scuff- and erosion-resistant insulating surface . . . or for a good adhesive bond between Min-K insulation and other surfaces. Or, it may be used to control high transient temperatures! For high heat capacity of asbestos-reinforced plastic combined with the low conductivity and heat capacity of Min-K result in a product that provides minimum heat transfer under transient conditions.

Min-Klad is now being tested for approximately two dozen missile and rocket designs. Why not investigate this new material for your present thermal requirements? Upon request, we'll be pleased to send you a sample of the material along with detailed technical information. Write Johns-Manville, Box 14, New York 16, New York. (Ask, too, for information on Min-K insulation and the new aviation insulation brochure IN-185A.) In Canada: Port Credit, Ontario.

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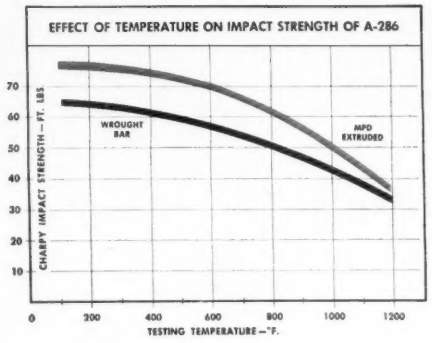
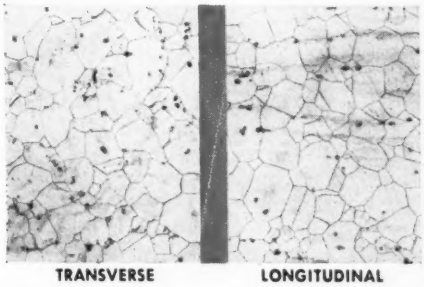
From melt to finished product, steel and other premium alloys are under constant, critical surveillance at the Metals Processing Division of Curtiss-Wright Corporation. CURMET commercial products have the same built-in precision qualities that have steadily surpassed rigid military and commercial specifications for many years.



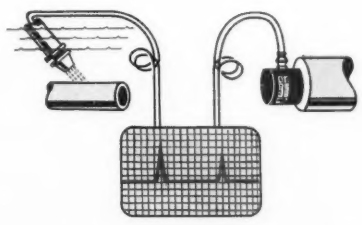
CURMET quality is more than inspection . . . though the most modern flaw detection methods are employed . . . it is the *in-process control of metal flow* that imparts premium properties and adds to service life.



TRANSVERSE LONGITUDINAL

CURMET processing with accurate metallurgical control is typified by this microphoto of a precipitation hardening, high temperature alloy extrusion (A-286) showing uniform longitudinal and transverse grains. Metallurgical examination of the extrusion shows uniformity of microstructure, assuring consistently high mechanical properties throughout the full length.

ULTRASONIC INSPECTION



IMMERSION TESTING — OR — CONTACT TESTING

Permissible ultrasonic flaw indication for commercial products is 5% of wall thickness. Nuclear applications are specified at 3%. High-performance A-286 alloy, when CURMET processed, consistently passes ultrasonic testing at the 1½% level . . . with no defects noted even under these rigid test conditions.

CURMET ultrasonic testing can be applied to your forged or extruded product by either the immersion or contact method. Simple or complex, solid or hollow, your product gains quality by CURMET in-process control.

FOR FURTHER INFORMATION WRITE

METALS PROCESSING DIVISION **CURTISS-WRIGHT CORPORATION**

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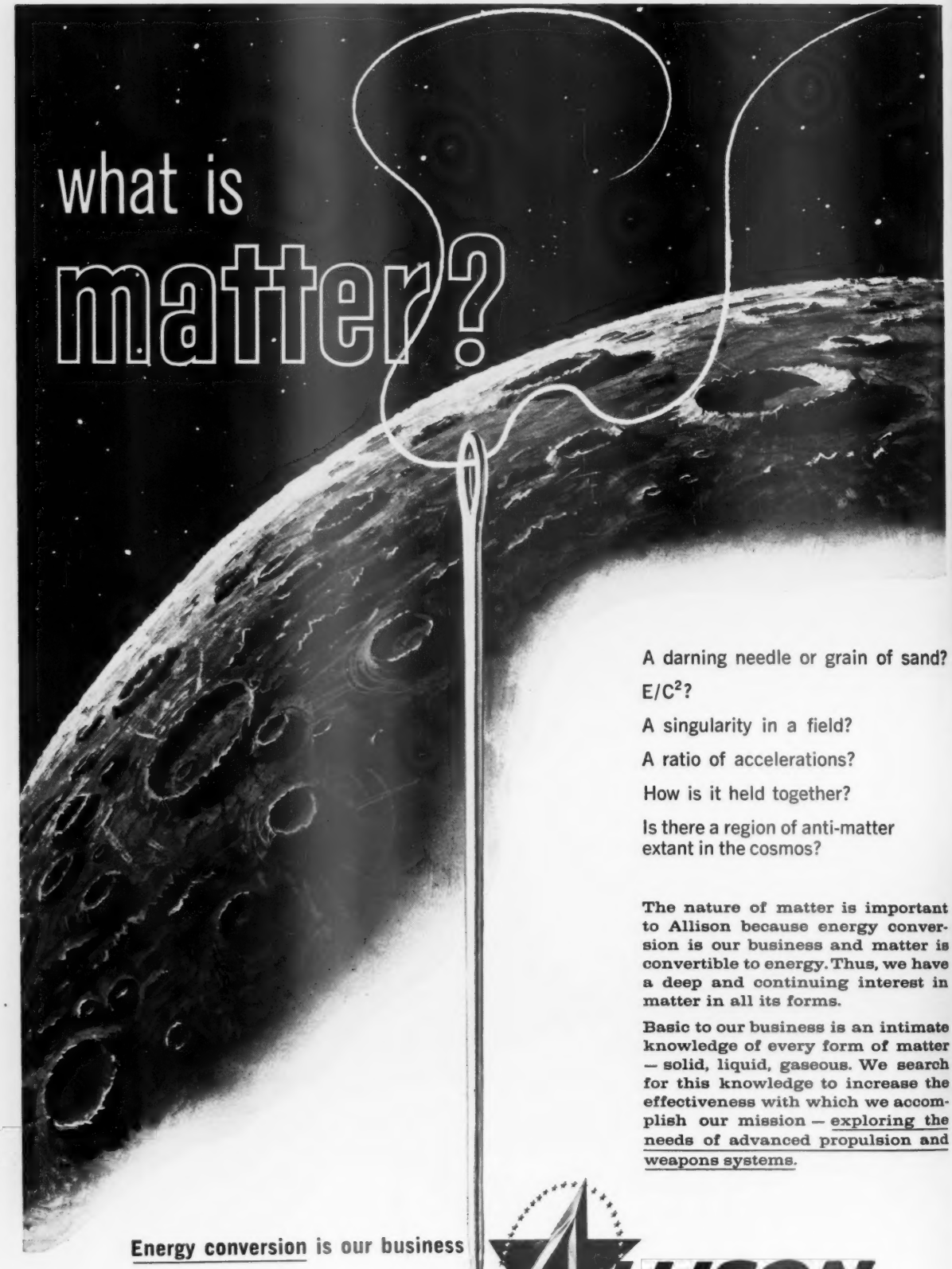

A darning needle or grain of sand?

E/C^2?

A singularity in a field?

A ratio of accelerations?

How is it held together?

Is there a region of anti-matter extant in the cosmos?

The nature of matter is important to Allison because energy conversion is our business and matter is convertible to energy. Thus, we have a deep and continuing interest in matter in all its forms.

Basic to our business is an intimate knowledge of every form of matter — solid, liquid, gaseous. We search for this knowledge to increase the effectiveness with which we accomplish our mission — exploring the needs of advanced propulsion and weapons systems.

Energy conversion is our business

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TO ENGINEERS AND SCIENTISTS:

Engineers capable of contributing to advances in the state-of-the-art and scientists who desire to do proof-of-the-principle research in the fields of propulsion systems, automatic controls, advanced test facilities and high temperature materials may find, here at Marquardt, the climate best suited to your interests and talents.
May I suggest that you contact me?

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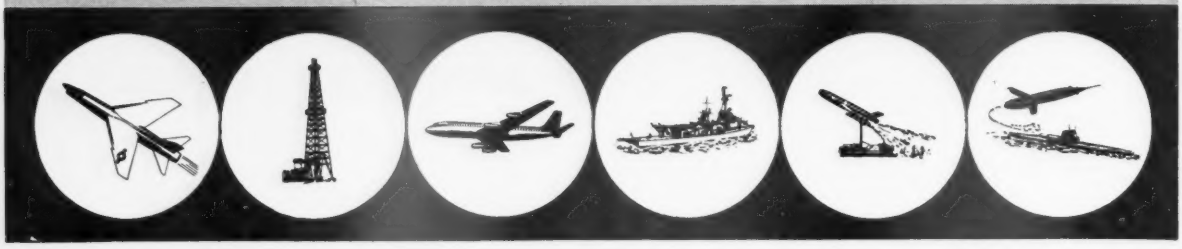
SERVO-SYSTEMS OF FORCE CONTROL



With 38 years acceptance Sargent builds precision linear and rotary hydraulic, pneumatic, mechanical and electronic systems of force control to meet successfully the increasingly high requirements of marine, aircraft, missile, petroleum and industrial use. From original idea to finished product – SARGENT.

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"GOOD WILL" is the disposition of the pleased customer to return to the place where he has been well treated.
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Sargent — QUALITY BUILDS GOOD WILL

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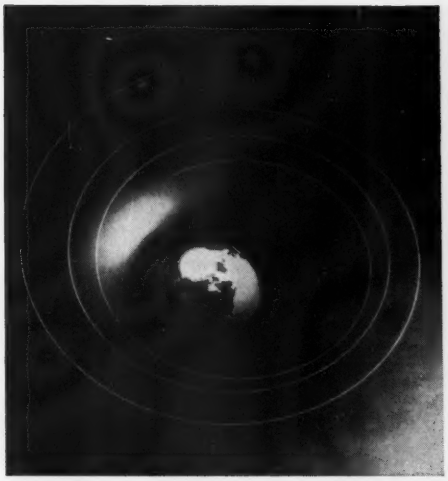
For Peaceful Purposes and the Benefit of All Mankind The National Aeronautics and Space Administration Announces its Authorization by the Congress of the United States



To Direct and Implement U.S. Research Efforts In Aeronautics and the Exploration of Space

"The aeronautical and space activities of the United States shall be conducted so as to contribute materially to one or more of the following objectives:

(1) The expansion of human knowledge of phenomena in the atmosphere and space;
(2) The improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles;
(3) The development and operation of vehicles capable of carrying instruments, equipment, supplies and living organisms through space;
(4) The establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes;
(5) The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere;
(6) The making available to agencies directly concerned with national defense of discoveries that have military value or significance, and the furnishing by such agencies, to the civilian agency established to direct and control nonmilitary aeronautical and space activities, of information as to discoveries which have value or significance to that agency;
(7) Cooperation by the United States with other nations and groups of nations in work done pursuant to this Act and in the peaceful application of the results thereof; and
(8) The most effective utilization of the scientific and engineering resources of the United States, with close cooperation among all interested agencies of the United States in order to avoid unnecessary duplication of effort, facilities, and equipment..."*

The excitement, the importance, and the scope of the National Aeronautics and Space Administration are apparent, we believe, from our enabling act. Career opportunities at NASA are as unlimited as the scope of the organization itself.

Please address your inquiry to the Personnel Director of any of the following NASA research centers. Your inquiry will be answered immediately, and will be treated in the strictest confidence.

Langley Research Center, Hampton, Virginia
Ames Research Center, Mountain View, California
Lewis Research Center, Cleveland, Ohio
High-Speed Flight Station, Edwards, California

*Quoted from the National Aeronautics and Space Act of 1958.

(Positions are filled in accordance with Aeronautical Research Scientist Announcement 61B)

NASA National Aeronautics and Space Administration

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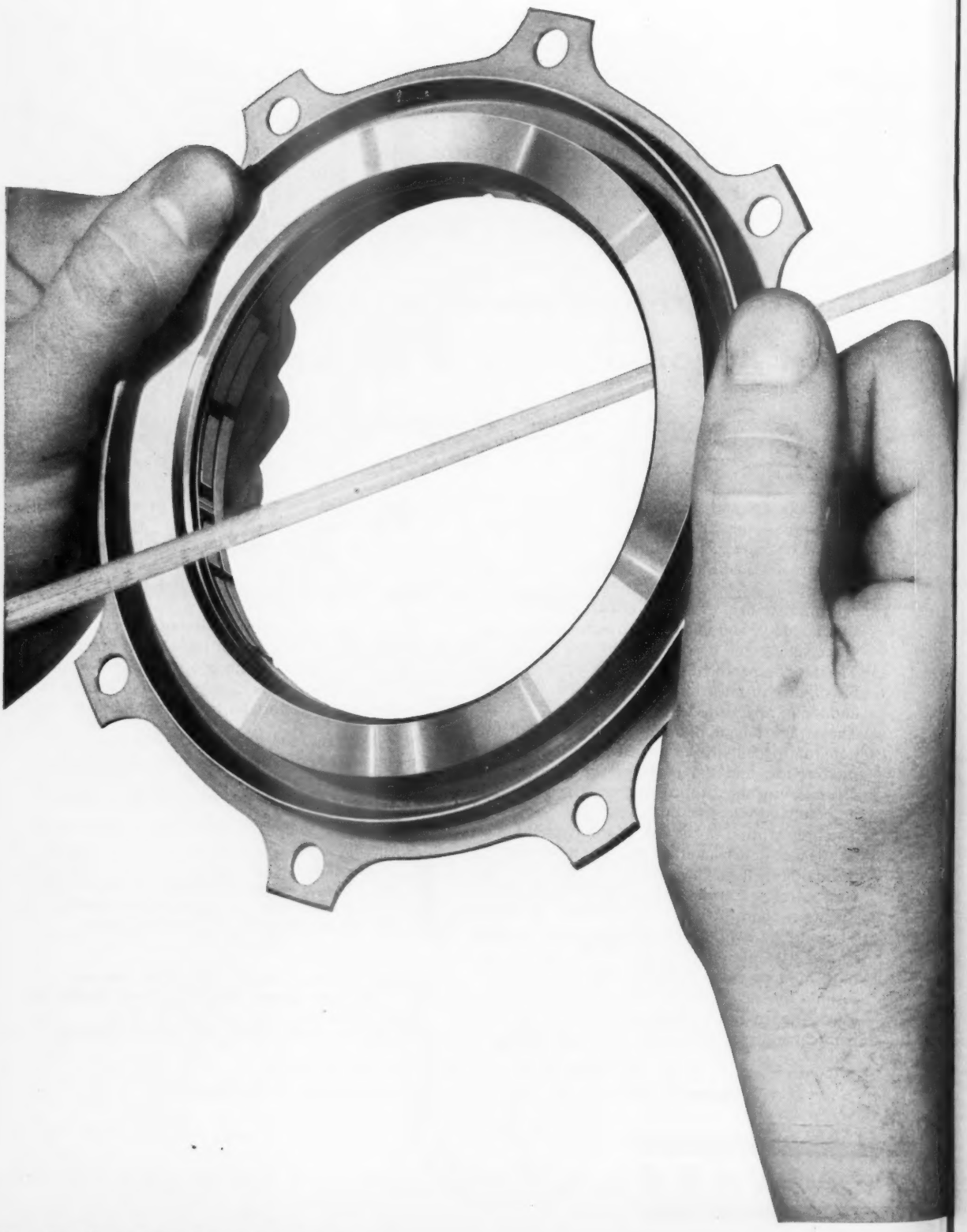

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A word about our Advertisers

The many companies whose advertising appears in this issue are interested in you and your work. They are anxious to let you know what they are doing to help you solve research and design problems in missile, rocket, air, and spacecraft projects.

AERO/SPACE ENGINEERING's advertising pages keep you posted on new and improved materials, components, services, and supplies useful to your professional work.

To request more information on any product or service advertised, may we suggest you use the green self-addressed reply cards inserted at the end of this issue. No postage is needed. Our staff will be glad to forward all requests to the proper companies for direct reply to you.

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★ Specifications and further information on the missile, rocket, and aircraft products of these companies will be found in the 1958 AERONAUTICAL ENGINEERING CATALOG

The only publication devoted exclusively to the aero/space industry, this CATALOG serves as a valuable buyers' and reference guide to sources and specifications on aircraft and missile parts and materials. It is distributed annually to Chief Engineers, Designers, Production Heads, and Purchasing Departments of all leading manufacturers of missiles, rockets, aircraft and spacecraft, and their related components; Government Agencies; Research Organizations; etc.

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INSTITUTE OF THE AERONAUTICAL SCIENCES
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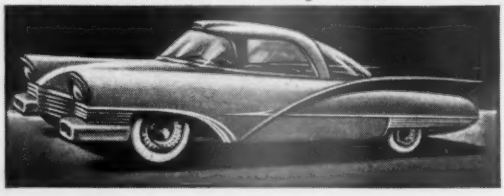
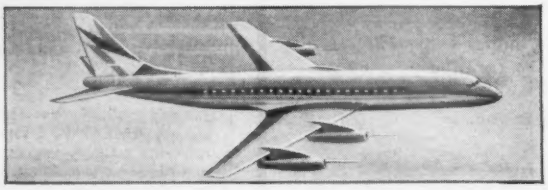
The steel plowshare was the basic agricultural tool when Wyman-Gordon was established seventy-five years ago. At that time, it took approximately 50 per cent of the nation's work force on farms to produce food for our country's needs.



With today's mechanical farm implements, it requires only 12½ per cent to feed our people. The development of modern farm implements, motor cars, trucks and tractors, railroad locomotives, and the "Mach era" aircraft and space vehicles, would have been impossible without forgings.

Whenever the ultimate is required in power, speed, endurance or reliability there is no substitute for a forging. Today, as for seventy-five years, Wyman-Gordon continues in the forefront in new forging developments.



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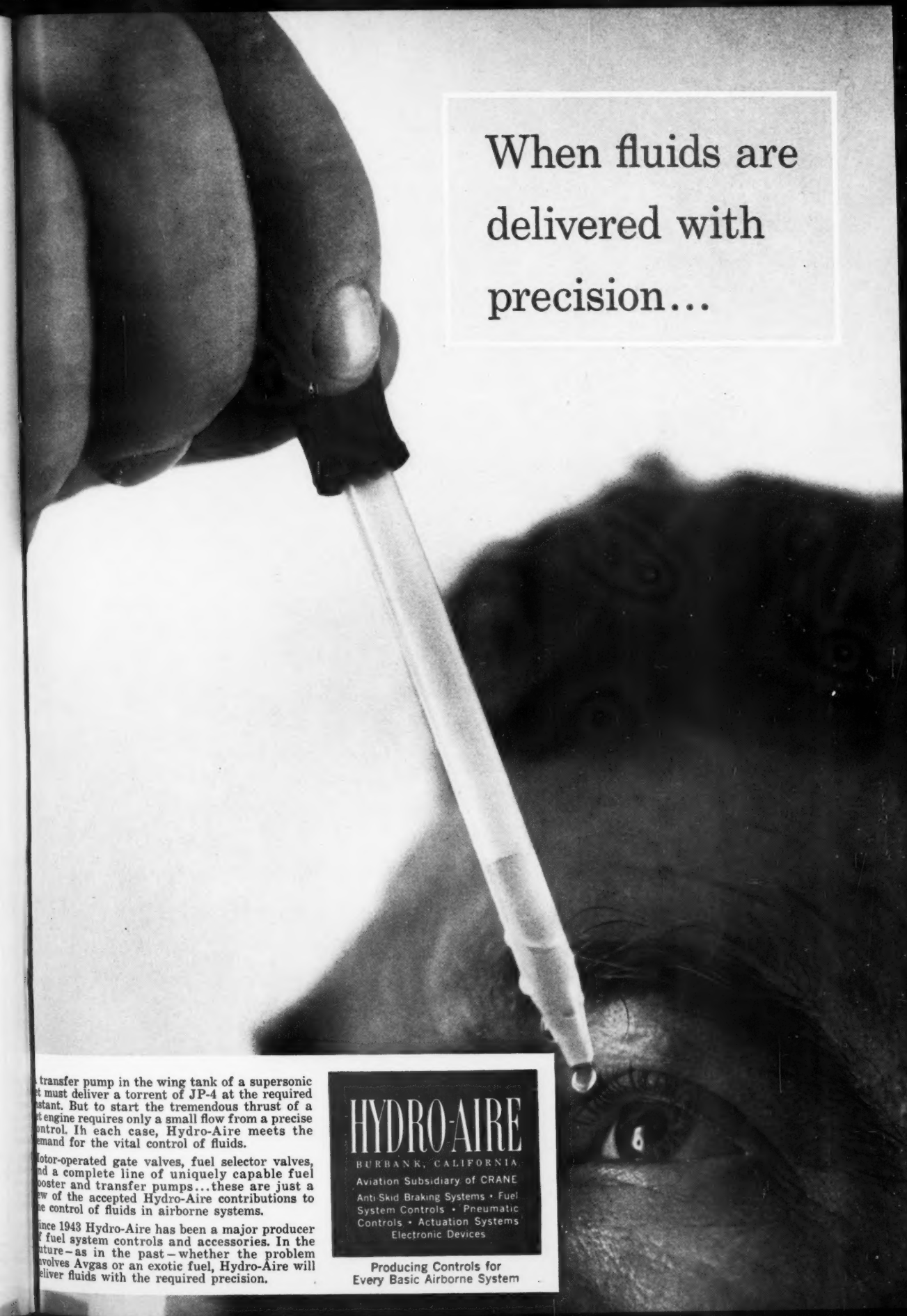

transfer pump in the wing tank of a supersonic
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